FEDERAL AID IN FISH RESTORATION
STUDY G-I-5

INVENTORY AND CATALOGING SPECIAL MANAGEMENT PROBLEMS

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ALASKA DEPARTMENT OF FISH AND GAME
James W. Brooks, Commissioner
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Annual Performance Report for

INVENTORY AND CATALOGING SPECIAL MANAGEMENT PROBLEMS

by

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RESEARCH PROJECT SEGMENT

State: ALASKA

Name: Sport Fish Investigations of Alaska

Project No.: F-9-8

Study No.: G-I

Study Title: INVENTORY & CATALOGING

Job No.: G-I-S

Job Title: Collection and Interpretation of Information Needed to Solve Special Management Problems

Period Covered: July 1, 1975 to June 30, 1976

Due to the specialized nature of the investigations being carried on under Job No. G-I-S, a separate section is devoted to each of the job objectives.

OBJECTIVES

1. Determine the effectiveness of hydroacoustic equipment in the estimation of fish abundance, distribution, and size of lakes.

2. Determine interspecific relationships for space and food between Dolly Varden and introduce rearing coho in a landlocked lake.

3. Determine the impact of any future flow variation from the Blue Lake Dam and hydroelectric facility, Federal Power Commission #2230, on the downstream sport fishery of Medvetcha River.

4. To continue, analysis, and organization of all available and new information on sport fish resources of southeastern Alaska.

OBJECTIVE 1: Determine the effectiveness of hydroacoustic equipment in the estimation of fish abundance, distribution, and size of lakes.

ABSTRACT

An evaluation of hydroacoustic techniques and the effectiveness of these techniques in estimating fish abundance, distribution, and size was attempted in several lakes. A review of literature demonstrated the usefulness of echo sounding to locate fish. A hydroacoustic system was purchased through Applied Physics Laboratory, University of Washington (A.P.L.); and a short course in the operation of the equipment was attended at the University of Washington. During the summer of 1975 acoustic surveys were conducted on three small lakes where the number of fish and/or species composition were known. Orton and Blue lakes, with isolated populations of Arctic grayling, Thymallus arcticus (Pallas), and rainbow trout, Salmo gairdneri Richardson, respectively, were each surveyed one time. Osprey Lake on Baranof Island was surveyed before and after coho salmon, Oncorhynchus kisutch (Walbaum), fry were introduced. Osprey Lake had an indigenous population of Dolly Varden, Salvelinus malma (Walbaum). No quantitative data on fish size or abundance were obtained from surveys because of equipment inadequacies, lake characteristics, and fish behavior.

BACKGROUND

One of the time-consuming problems fishery biologists encounter is how to accurately determine fish distribution and abundance in lakes. In the past this has been attempted using several types of gill nets, fyke nets, hoopnets, trapnets, electroshockers, and a multitude of various fish traps. These methods can be very selective for a given species or size of fish and therefore yield biased results. The behavior patterns of a given species may even produce problems which result in an existing population not being detected.

Population estimates derived from conventional methods are accomplished by mark and recapture techniques, which are very time consuming and depend upon the behavior of the test animal. In order to attain any degree of accuracy a large percentage of the population must be marked; this necessitates repeated sampling of the same lake.

An analysis of the literature clearly demonstrates the applicability of using hydroacoustic techniques to locate fish. The first systematic use of acoustics to detect fish was in 1933 when an echo sounder was used to locate herring in the North Sea. From 1940 to 1960 acoustic observations were made of fish distribution, abundance, and behavioral traits such as diurnal movements, seasonal changes in abundance, and migration routes. Since that time pulse counters, echo integrators, and computer techniques have advanced hydroacoustic technology, so it is now a valuable tool in marine fishery investigations.

An acoustic system developed at the University of Washington has been used in several large freshwater lakes. A survey of Lake Chelan, Washington

(Croker and Mathisen, 1972), was conducted for the purpose of estimating fish distribution as a function of depth and light. A survey of Lake Wenatchee, an oligotrophic lake on the eastern side of the Cascade Mountain Range, was conducted for the purpose of estimating the number of juvenile sockeye salmon and their distribution (Nannallee and Mathisen, 1972). Yet another sample of the usefulness of this acoustic system is described by Lemberg (1975) in a hydroacoustic assessment of the 1973 sockeye salmon escapement into Lake Quinault, Washington.

In 1973 Nannallee compiled publications relating to the acoustic data acquisition system developed at the University of Washington and described the various components and their operations in language understandable to fishery biologists. In this paper he presented a user's manual describing the workings of the data acquisition system and its setup and operation in the field.

In 1974 a Ross 400A echo sounder was purchased through A.P.L. Adjustment of the Ross 400A to proper sensitivity settings allowed detection of fish. Echo traces on the recording paper indicated fish distribution in Auke Lake. No quantitative data on fish size or abundance could be determined with the chart recorder. The system components needed to allow determination of fish abundance and size (interface amplifier, tape recorder, oscilloscope, and circuit modifications) were not purchased until 1975.

RECOMMENDATIONS

1. No further attempt to quantify fish populations in small lakes by hydroacoustic techniques should be attempted by the Alaska Department of Fish and Game until further research and development of an applicable system is completed.

2. This project should attempt to trade the hydroacoustic data acquisition system to a project that can utilize it.

TECHNIQUES USED

Literature Search

A literature search concerning use of hydroacoustic techniques in the estimation of fish abundance, distribution, and size in lakes was conducted to determine applicability of the technique. The literature discussed in the "Background" section along with the literature review presented last year (Schmidt and Robards, 1975) provides a comprehensive summary of literature applicable to the problem.

System Description and Calibration

The hydroacoustic system components needed to make possible a determination of fish abundance and size were purchased in spring 1975. All equipment was standardized by A.P.L. so data could be compared.

A short course in Acoustic Stock Estimation, which addressed itself to operation of equipment developed for stock assessment, target strength analysis, survey design, and interpretation of results, was attended at the University of Washington, College of Fisheries.

Hydroacoustic Surveys Conducted and Procedure for Surveys

Acoustic surveys were conducted on three lakes where the number of fish and/or species composition were known. Osprey Lake on Baranof Island was surveyed before and after coho salmon, *Oncorhynchus kisutch* (Walbaum), fry were introduced. This lake has an indigenous population of Dolly Varden, *Salvelinus malma* (Walbaum). Comparison of these data with a reliable population estimate from mark-recapture indices would provide valuable insights on how to interpret acoustic data from small lakes. Orton and Blue lakes, with isolated populations of Arctic grayling, *Thymallus arcticus* (Pallas), and rainbow trout, *Salmo gairdneri* Richardson, respectively, were each surveyed one time.

One acoustic survey was run on Auke Lake. This is an anadromous system with several fish species present. At the time of the survey the lake contained several species and all sizes of fish.

Prior to the start of each acoustic survey the towing vehicle depth was adjusted to eliminate surface interference or interference caused by the boat wake. Boat speed was set with a Gurley current meter. Periodic checks were made to maintain a constant speed. The system receiver gain was then set. This setting was referenced to a level which produced maximum target voltage to system noise without causing tape saturation. A voice check and calibration tone indicating receiver gain were recorded on magnetic tape before the start of all transects. This provided a way to detect system drift in the field and to calibrate and analyze all transects at a constant gain. Because the receiver contained a time varied gain circuit approximated by 20 log R (where R is depth), the calibration tone voltage was referenced to a specific time, i.e., 50 ms. An echo sounder pulse rate of 6 sec was used for all surveys.

Analyses of Hydroacoustic Data

Visual Processing:

Data processing was attempted by visually interpreting information as the tapes were played back. Echo traces were displayed on the oscilloscope screen at the recorded rate of 61 sec. The magnetic tapes were recorded and played back at a speed of 4.76 cm/sec. Time delay (ms) on the oscilloscope display referenced to the beginning of the transmit pulse represented depth. The dispersion of sound through fresh water at 5°C requires 1.40 ms/sonar m. When oscilloscope sweep speed was set at 10 ms/division, each major division on the oscilloscope screen represented a 7.13 m depth interval.

Individual 10 ms depth (time) intervals corresponding to specific 7.13 m depth intervals were displayed across the full width of the screen by utilizing a 10X expansion function. Fish signals were recognized by their pulse length (0.6 ms) and their successive sonar reflections (insonifications) at the same depth.

Analysis of acoustic data should consist of three steps as described by Lemberg (1975). First, distributions of target strengths are used to establish counting thresholds so specific size groups of fish can be separated from the population. Second, fish targets within length groups are counted visually. Third, the acoustic sample volume is calculated. From these data estimates of fish density are derived in each of the 7.13 m depth intervals. A total abundance estimate for a lake is computed by combining strata estimates.

Target Strengths and Counting Thresholds. Acoustic target strength (TS) is defined as $TS = 10 \log_{10} (4\frac{\sigma}{\pi})$. The scattering cross section of a fish target is dependent on the aspect of a fish and its composition (bones, flesh, air bladder, etc). Mean target strength increases with fish length (Midttun and Hoff, 1962; Cushing, 1963; Lowe, 1971; Johannesson and Losse, 1973).

Target amplitudes are related to target strength values by the target strength equation:

$TS = TV - SL - S_x - SG + (40 \log_{10} R + 2\alpha R)$ where

TS = target strength in dB,

TV = target voltage, dB/1 volt,

SL = source level, dB//1µBar ref. 1 yd.,

$= V_T + T_x$,

where V_T = transducer driving voltage, dB//1 volt, and

T_x = transducer transmitting sensitivity, dBµ//1 volt,

S_x = transducer receiving sensitivity, dBv/µBar,

SG = system gain at time (depth) R, dB//100µV (signal output//calibration signal input),

R = distance to target (yd), and

a = attenuation coefficient, dB/yd

(from Nunallee and Mathisen, 1972).

Ross sounders do not have an ideal time varied gain (TVG) circuit to compensate for echo level changes due to propagation losses. The TVG inaccuracies must be removed to obtain accurate estimates. One method for correcting the TVG is to use a threshold level that varies with depth. The equation for the threshold in dB as a function of depth is:

$T(D) = T + G(D) - (40 \log_{10} D + 2\alpha D)$ where D is the depth, G(D) is the sounder gain as a function of depth, and T is a fixed threshold (given target strength). The counting threshold as a function of depth can be drawn on a piece of plastic and placed on the oscilloscope screen used for echo counting. This method of correcting TVG error can also be implemented on a computer.

Fish Signal Enumeration. The enumeration procedure consisted of sequentially examining the individual depth strata (7.13 m) of each transect for fish targets producing voltages above a counting threshold. When an insonification surpassed the threshold, the magnetic tape was stopped, reversed, and played forward again so the total detections above ambient noise were counted. The exact depth of each target was also recorded.

Determination of Effective Sample Volume. Circular transducers are designed so the greatest portion of acoustic energy is transmitted in a unidirectional cone perpendicular to the face of the transducer. The interaction among the factors which establish the boundary conditions of the cone such as the sound intensity dispersion characteristics of the transducer, target size, aspect, and depth, and receiver sensitivity are discussed by Nunnallee(1973). Because the factors do not remain constant with time, independent estimates of acoustic sampling volume must be calculated for every survey.

The dimensions of the acoustic energy cone can be defined by target detectability within the cone. A sample·volume determination involves counting the number of times that fish targets are detected (insonified) within the region of detectability at depth planes of interest as the transducer passes over the fish at a known speed.

A mean chord length for each depth plane is determined empirically by:

$$E(c) = \frac{\text{Boat speed (m/sec) x mean no. insonifications/fish (pulses)}}{\text{Sounder pulse rate (pulses/sec)}}$$

The expected mean chord length through a circle for a uniform distribution is:

$$E(\hat{c}) = \frac{\pi}{2} r$$

where $E(\hat{c})$ = expected mean chord length, and
r = circle radius

(from Nunnallee and Mathisen, 1972).

Usually the radii are calculated for the circular planes corresponding to the upper and lower limits of the strata being sampled. The pulse volume for each interval is then approximated by either a cylinder (Nunnallee and Mathisen, 1972) or the frustum of a right cone (Croker, 1973).

During the present study a pulse volume was calculated by the formula $V = \pi r^2 h$ with $h = 7.13$ m.

Methods for estimation of fish density and abundance are well described by Lemberg (1975).

Computer Analysis:

An attempt was made to arrange for computer processing of magnetic tapes at A.P.L. A misunderstanding between personnel at A.P.L. led me to believe that computer software was available for such processing. I was later informed that a computer program for individual echo counting analysis was not available but could be developed (Ehrenberg, 1975).

RESULTS

System Description and Calibration

The system (Figure 1) consists of 105 KHz Ross 400 Surveyor echo sounder (transceiver and chart recorder), interface amplifier, and a Nakamichi 700 stereo cassette tape recorder. Modifications to the echo sounder include replacement of the single turn potentiometer with a 10 turn vernier control potentiometer installation of a 100µV calibration oscillator, and associated wiring modifications.

The acoustic data are collected at 105 KHz and converted by the interface amplifier to a frequency level (5 KHz) compatible with the dynamic range of the tape recorder. It is then recorded on magnetic tape and becomes available for later analysis.

The Ross transducer measures 10 cm in diameter and produces an 8° circular beam at the -3 dB point. The transducer is mounted on a towing vehicle and suspended alongside the boat during transecting. The system is monitored by an oscilloscope, Tektronix 422, during operation.

Power to all system components is supplied by a frequency stable (± .05%) 60 Hz alternating current inverter manufactured by Topaz Electronics. The inverter supplies 115 V rms (root mean square) AC power from two 12 V storage batteries.

The system is portable for use from small boats. All system components are housed in cushioned plywood boxes.

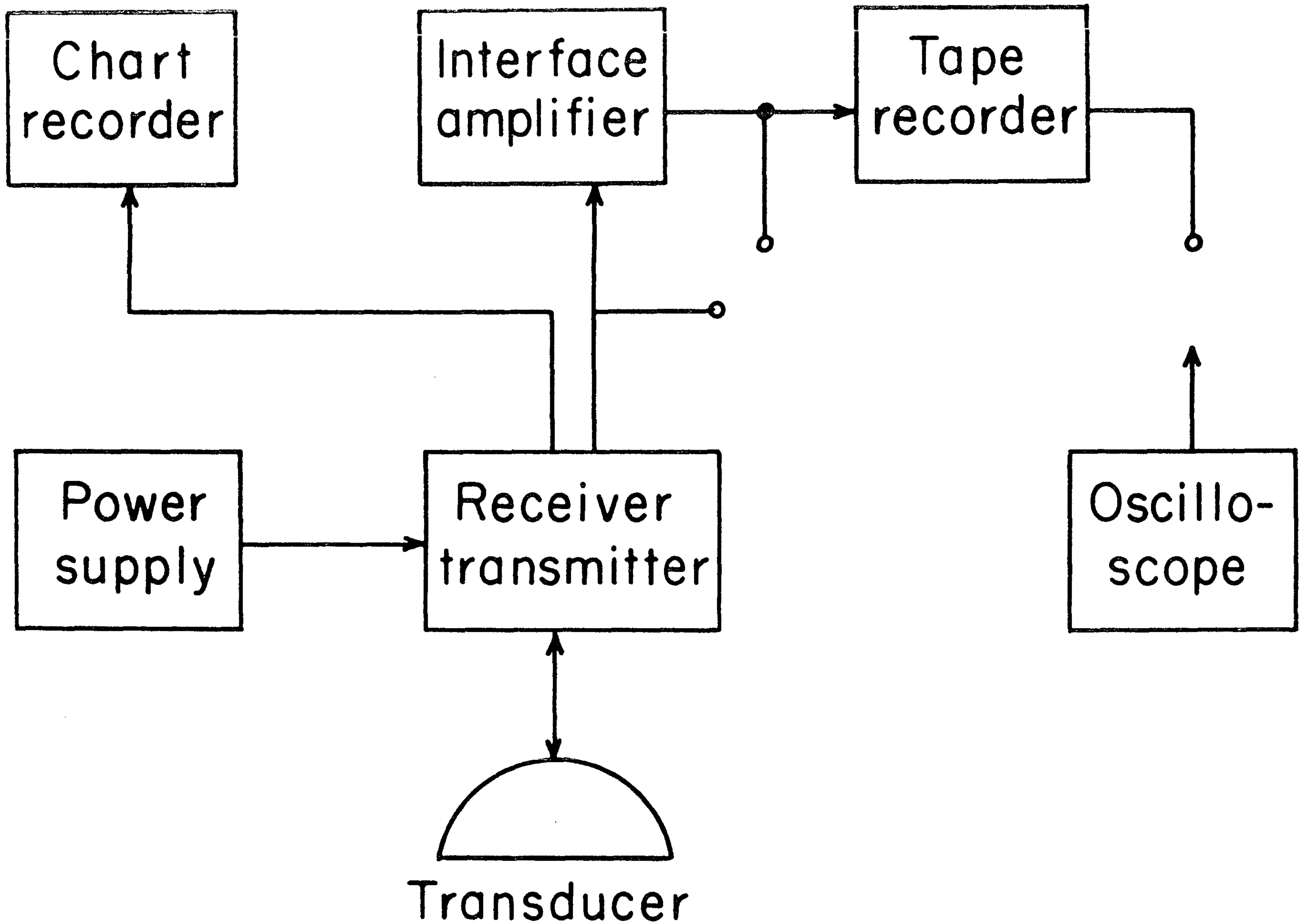

Figure 1. Block Diagram of Echo Recording System.

Calibration of system components was essential in order to employ the Target Strength equation:

$TS = TV - SL - S_X - SG + (40 \log_{10} R + 2\alpha R)$ where

TS = target strength in dB,

TV = target voltage, dB//1 volt,

SL = source level, dB//1μBar ref. 1 yd,

= $V_T + T_X$,

where V_T = transducer driving voltage, dB//1 volt, and

T_X = transducer transmitting sensitivity, dBμ//1 volt,

S_X = transducer receiving sensitivity, dBv/μBar,

SG = system gain at time (depth) R, dB//100μV (signal output// calibration signal input),

R = distance to target (yd), and

α = attenuation coefficient, dB/yd.

Transducer directivity, transmitter sensitivity, transmitting power response (Figure 2), and receiving sensitivity (Figure 3) of the Ross transducer No. 319 were determined at A.P.L. The transducer driving voltage was determined to be 42.56 dB//1 V, yielding a source level of 122.76 dB//μBar.

A calibration oscillator was used to calculate system gain (SG). It was built into the system and applied a known voltage (100uV) to the echo sounder receiver. The corresponding output was recorded on magnetic tape prior to running transects. A 20 log R time varied gain circuit in the receiver caused the output tone to increase with time (depth) after the transmit pulse. Since the input voltage was known, it was possible to determine the gain at any depth by measuring the related output. Changes in the amplitude of the calibration tone occurring among transects or surveys could then be corrected to a constant reference amplitude with the aid of an oscilloscope. System gain was calculated at the midpoints of depth strata where target voltage measurements were made.

The 40 log R term corrected for loss in sound intensity caused by the geometric spreading (square law effect) during two-way transmission. All distances were measured in yards and all targets were referenced to a depth of 1 yd. The attenuation coefficient (α) in fresh water is 0.00425.

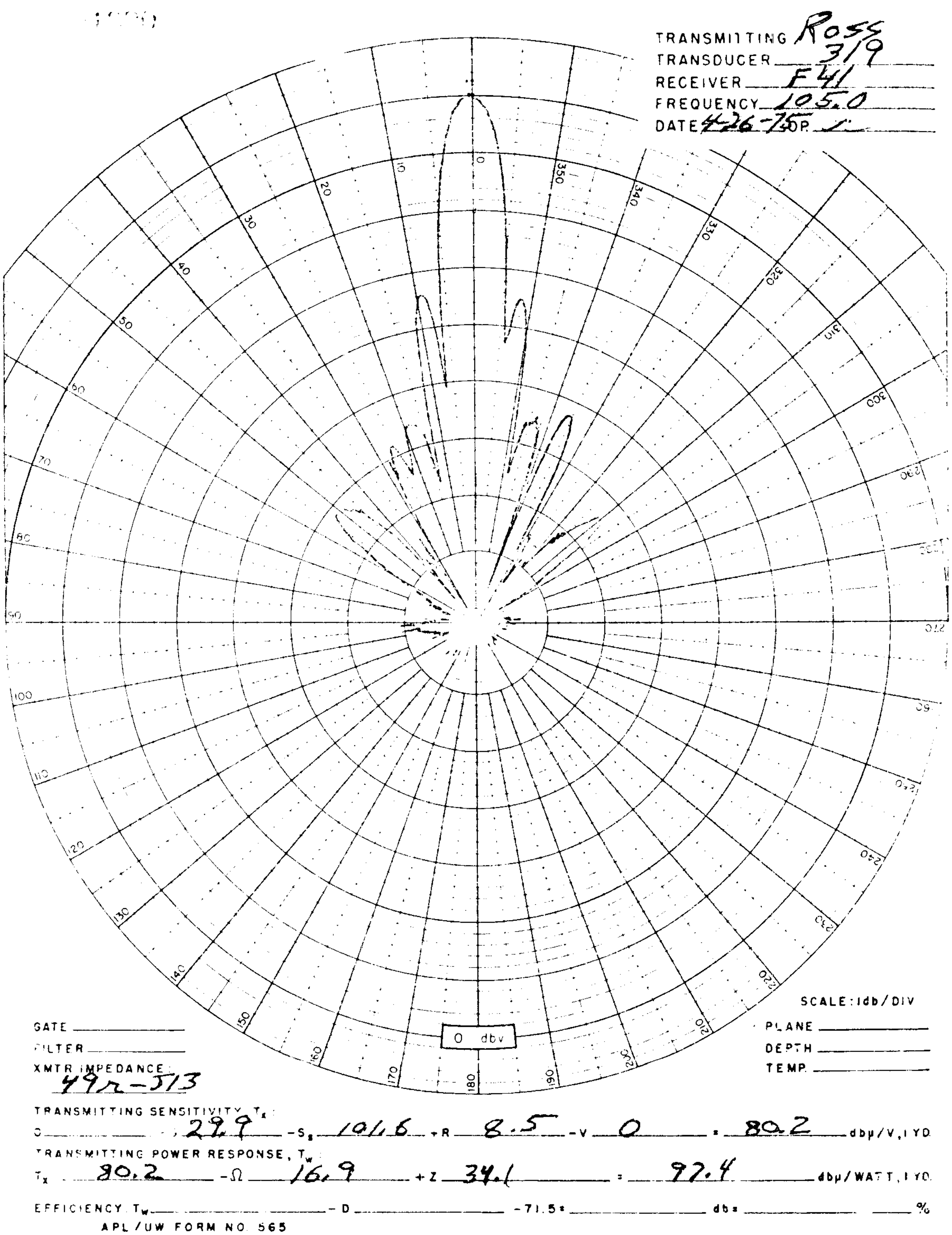

Figure 2. Transducer Directivity, Transmitting Sensitivity, and Transmitting Power Response of No. 319 Transducer, April 26, 1975.

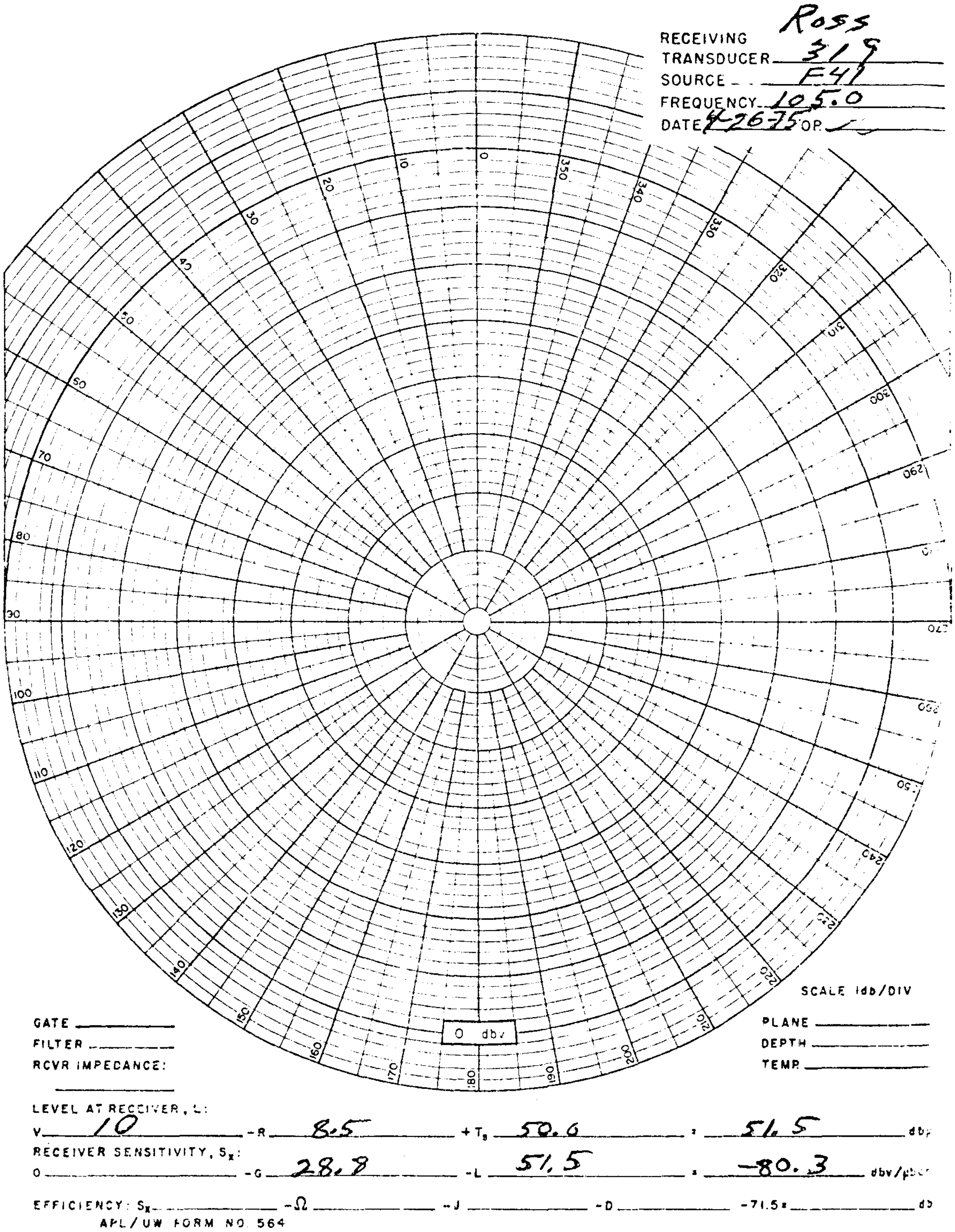

Figure 3. Receiving Sensitivity of Ross No. 319 Transducer, April 26, 1975.

Target voltages (TV) were measured in peak voltage and referenced to 1 V in order to change the measurements into decibels. Target voltage (TV), system gain (SG), and the transducer driving voltage (V_T) were converted to decibels (dB) by:

$$dB = 20 \log \frac{E_2}{E_1},$$

where

E_2 = measured voltage (output)

E_1 = reference voltage (input).

The calibration oscillator input was in root mean square (rms) voltage which necessitated transforming other voltage measurements to rms voltage prior to determining decible values. Voltage rms = 0.707 Vpp or .3535 Vpp.

Calibration checks were conducted on the transmitting and receiving components to assume stability of the system before each survey was conducted.

The response of the receiver was checked by comparing output signal strength from the 100µV calibrator with output levels determined at the time of original calibration. Procedure is as follows: (1) Interconnect entire system as for normal survey operations, (2) Submerge transducer in water, or replace transducer with 50.23 ohm resistive load, (3) Press 100µV calibrator button, and (4) Monitor voltage output from "Signal" on transceiver with oscilloscope. Prescribed sensitivity gain settings and desired output levels are: 9.0 = 8.91 Vpp or 3.15 Vrms; 7.0 = 1.10 Vpp or 0.39 Vrms; 6.0 = 0.46 Vpp or .164 Vrms; 5.0 = 0.236 Vpp or 0.0835 Vrms.

Noise grass from system with no signal from calibrator and 50.23 ohm resistive load across transducer terminals should be 0.02 Vpp when gain is on 9.0. Noise spikes may be as high as 0.3 Vpp.

Transmitting power was checked by determining voltage across transducer terminals with the oscilloscope. With transducer connected and submerged, voltage should be 380 Vpp.

The Nakamichi 700 cassette recorder must be calibrated before a survey is begun. The right channel (signal input) is calibrated by adjusting the "record level" control of the tape deck so that a 1 Vpp input from the transceiver deflects the dB meter to -8 dB (red mark on Nakamichi dB meter). Recording and playback response from the Nakamichi 700 (Table 1) had best linearity at this setting.

Table 1. Recording and Playback Voltages* From Nakamichi 700 Cassette Recorder With 1 Vpp Input Signal Adjusted to -8 dB on Record Level Indicator.

Record Level (Vpp)	Playback Response (Vpp)
0.10	0.10
0.20	0.20
0.50	0.49
1.50	1.44
1.75	1.64
2.00	1.84
3.00	2.40

*Recordings made on Maxell UD_R C90 cassette recording tape.

Hydroacoustic Surveys Conducted

Hydroacoustic surveys were conducted on Osprey (Figure 4), Auke (Figure 5), Orton (Figure 6), and Blue (Figure 7) lakes. A summary of hydroacoustic surveys and pertinent field information is presented in Table 2.

Analysis of Hydroacoustic Data

Hydroacoustic surveys and corresponding data analysis are discussed chronologically in sequence of surveys conducted.

Osprey Lake, July 9:

The first survey was conducted on Osprey Lake, July 9.

In order to compare the two population estimates conducted on Osprey Lake, a target strength threshold corresponding to a 60 mm F.L. (fork length) fish was used. This allows for detection of both coho salmon and Dolly Varden in the September 3 survey, yet eliminating those fish smaller than 55 mm F.L. which would not be retained by minnow traps. Johannesson and Losse (1973) expressed the relationship between target strength and fish size as TS = 28 log L-76 where target strength is in decibels and L is fork length in cm. According to this formula, a 6 cm fish has target strength of -54 db.

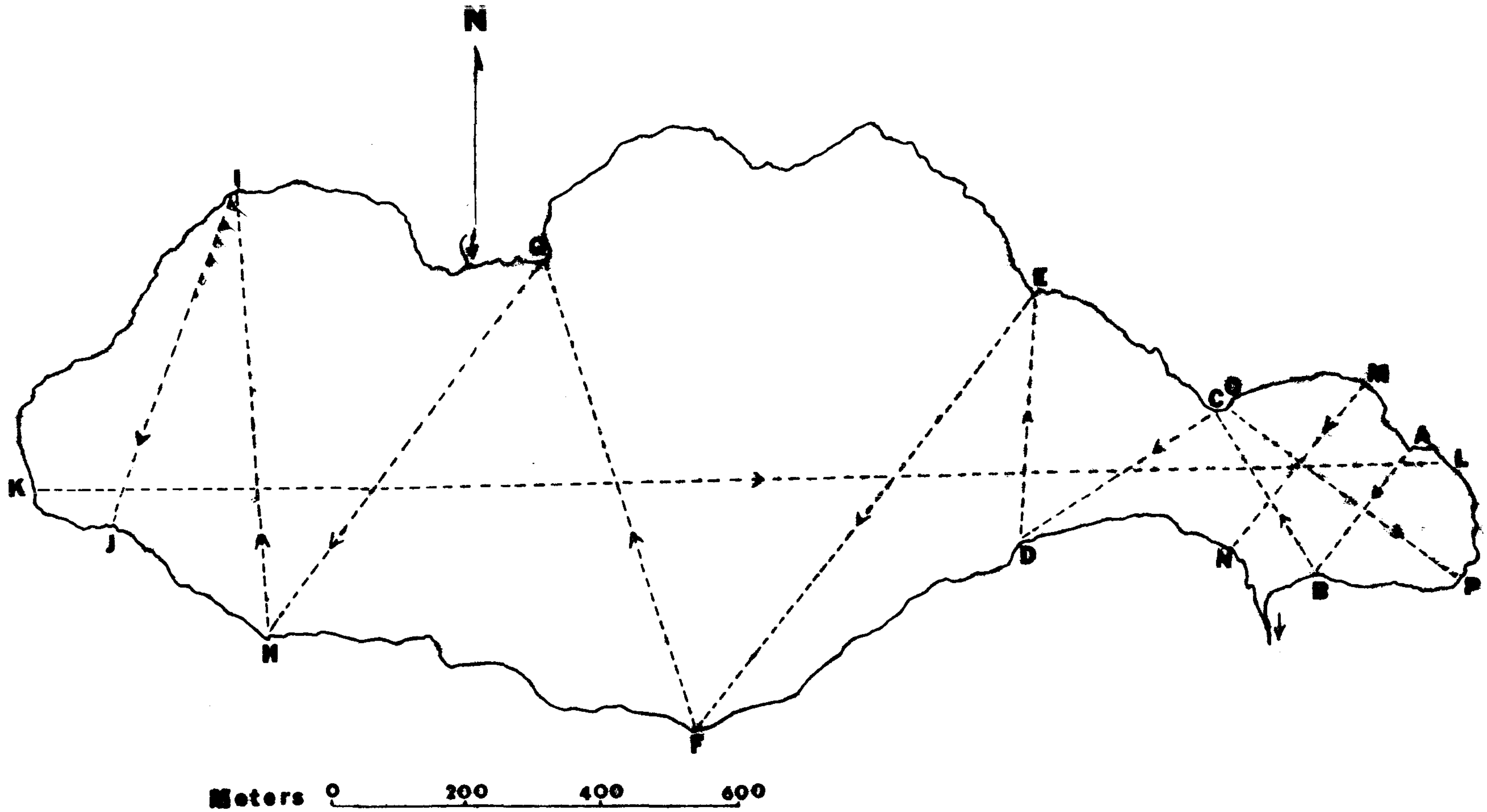

Figure 4. Hydroacoustic Transects Run on Osprey Lake, 1975.

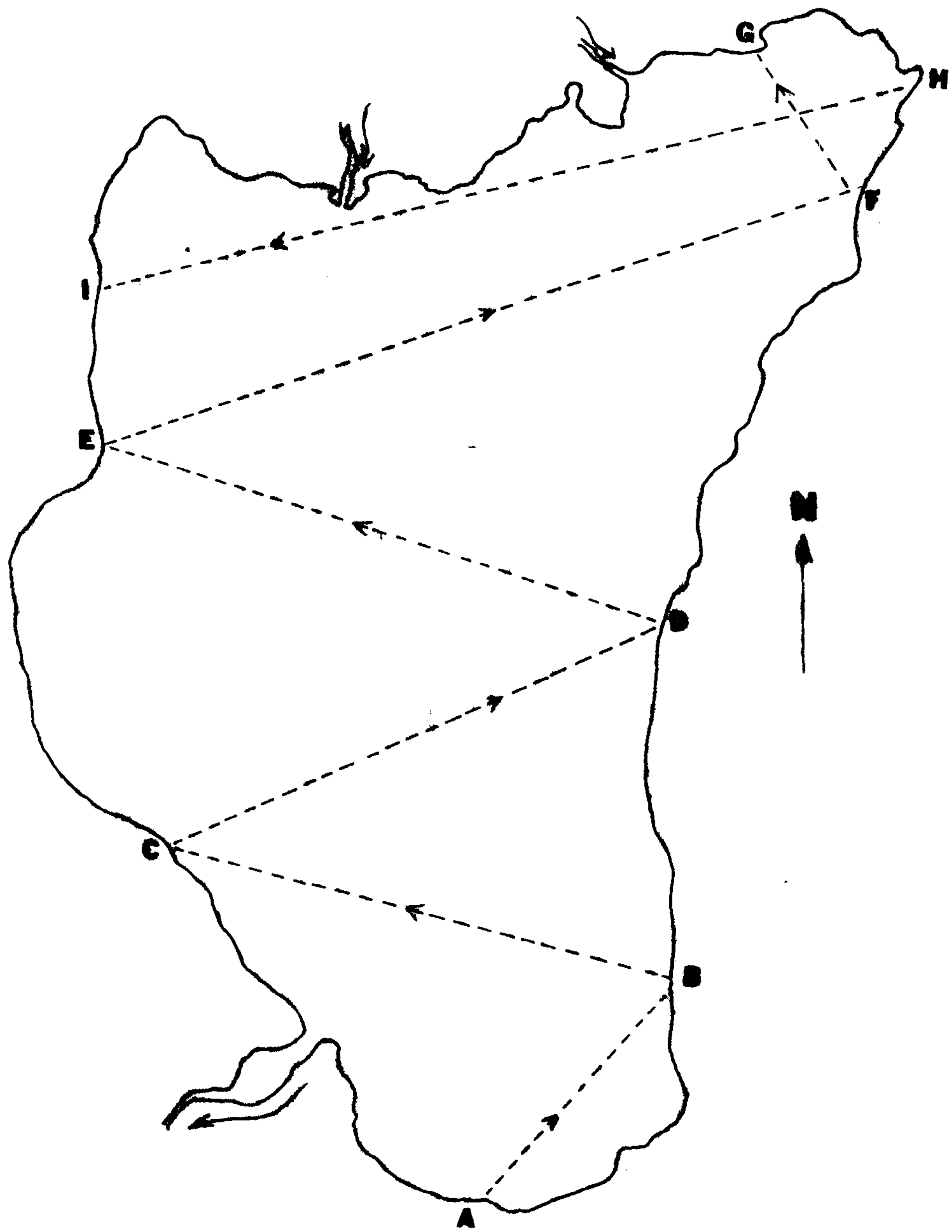

Figure 5. Hydroacoustic Transects Run on Auke Lake, 1975.

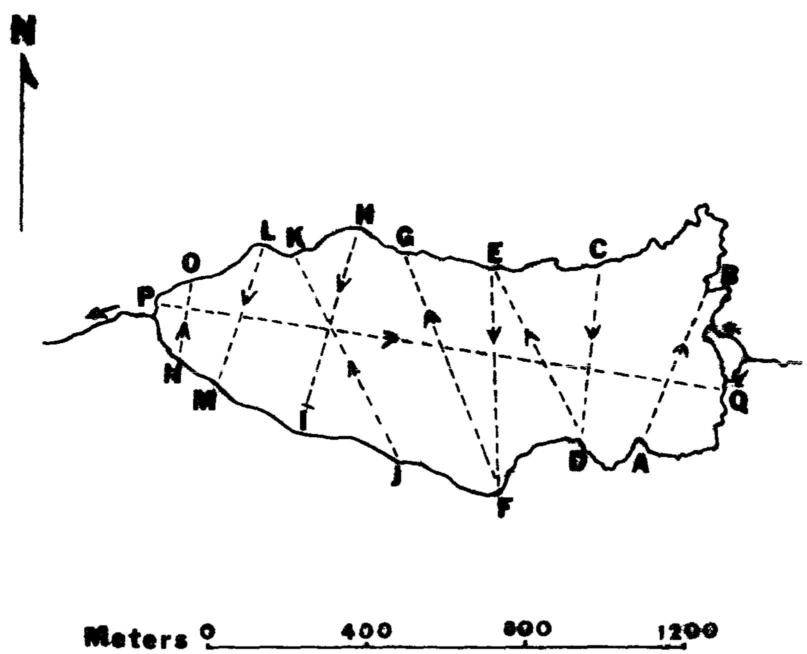

Figure 6. Hydroacoustic Transects Run on Orton Lake, 1975.

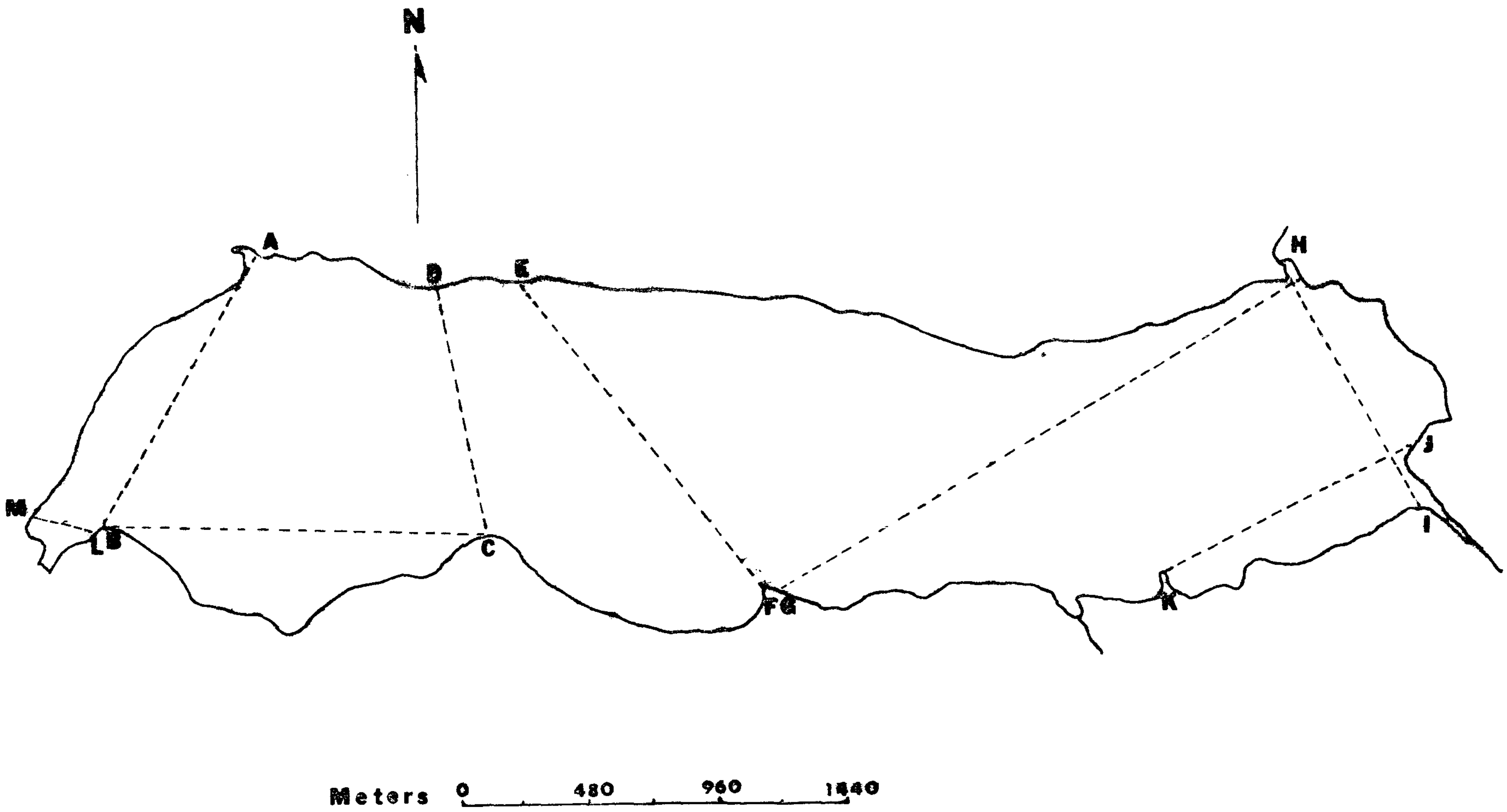

Figure 7. Hydroacoustic Transects Run on Blue Lake, 1975.

Table 2. Summary of Hydroacoustic Surveys Conducted, 1975.

Lake and Date	Time	Sounder Gain	Interface Amplifier Attenuation	TVG Ramp	Calibration Tone (Vpp)	Boat Speed (m/sec)
Osprey Lake						
July 9, 1975	11:55 a.m.-2:47 p.m.	7.0	-12 dB	-8 V	0.31	1.0
September 3, 1975		7.0	-12 dB	-18 V	0.31	1.25
Auke Lake						
August 2, 1975	1:10 p.m.-2:03 p.m.	7.5	-12 dB	-18 V	0.5	1.23
Orton Lake						
September 11, 1975		7.0	-12 dB	-18 V	0.31	
Blue Lake						
August 27, 1975		7.0	-12 dB	-18 V	0.31	

Lemberg (1975) found that target strength of -54 to -57 dB represented the sockeye salmon fry in Lake Quinault, Washington. Other acoustic surveys of sockeye salmon in Washington indicate that a target strength of -54 dB separated resident fish from recently recruited juvenile salmon (Dawson, Thorne, and Traynor, 1973). The growth of fry during the summer months places them in a larger category in the fall and winter. A counting threshold of -54 dB then should include the juvenile coho salmon in Osprey Lake but eliminate any Dolly Varden fry or other small targets, i.e., aquatic insects.

The combination of sensitivity (7.0), attenuation (-12 dB), and TVG ramp (-8 V) settings used during this survey resulted in high counting threshold voltages (Table 3). The Ross gain with the TVG ramp at -8 V differed greatly from the normal 40 log R + 2αR curve (Table 4), accounting for this high threshold curve. The high counting threshold voltages resulting from the improper TVG ramp negated any meaningful data interpretation.

Auke Lake Survey, August 2:

A hydroacoustic survey was conducted on Auke Lake after the TVG ramp of the Ross was recalibrated to -18 V. The Ross system gain more closely approximated the 40 log R + 2αR curve with this ramp setting (Table 5), so ramp setting was not changed during any of the subsequent surveys.

An estimation sampling volume or pulse volume was calculated based on the formula $V = \pi r^2 h$, where V = volume of a frustum of a right cone from a cylinder of approximation r = radius and h = height.

After collecting a sufficient number of target counts, a mean chord length for each plane is determined empirically by:

$$E(c) = \frac{\text{Boat speed (m/sec) x mean no. insonifications/fish (pulses)}}{\text{sounder pulse rate (pulses/sec)}}$$

The expected mean chord length through a circle for a uniform distribution is:

$$E(\hat{c}) = \frac{\pi}{2} r$$

where $E(\hat{c})$ = expected mean chord length, and
r = circle radius

(from Nunnallee and Mathisen, 1972).

Estimations of pulse volume by depth interval are presented in Table 6. These volume estimates are based on total insonifications for all targets detected per depth interval, so would not be representative volumes for population estimation of any given size fish.

Table 3. Counting Threshold Voltages by Depth (ms) for Three Sensitivity Settings on Ross Sounder, Assuming a -54 dB Target Strength.

Time (ms)	Auke Lake, August 2 Sensitivity 7.5 Attenuation -12 dB -18 V TVG Ramp		Osprey Lake, September 3 Sensitivity 7.0 Attenuation -12 dB -18 V TVG Ramp		Osprey Lake, July 9 Sensitivity 7.0 Attenuation -12 dB -8 V TVG Ramp	
	dB	Vp	dB	Vp	dB	Vp
5	2.93	1.01	-10.11	.43	18.16	11.44
10	-12.47	.34	-18.12	.18	7.32	3.28
15	-15.28	.24	-20.63	.13	1.96	1.77
20	-16.96	.20	-21.97	.13	-2.77	1.03
25	-17.84	.18	-22.4	.11	-4.88	.81
30	-19.31	.15	-23.42	.09	-8.17	.55
35	-19.36	.15	-23.6	.09	-10.22	.44
40	-19.41	.15	-23.84	.09	-11.98	.36
45	-19.76	.14	-24.07	.09	-13.86	.29
50	-19.97	.14	-24.17	.09	-15.49	.24
55	-20.34	.14	-24.27	.09	-16.87	.20
60	-20.74	.13	-24.78	.08		
65	-21.25	.12	-25.34	.08		
70	-21.91	.11	-25.9	.07		

Table 4. Ross System Gain at Depth for Sensitivity of 7.0, Attenuation of -12 dB, and TVG Ramp of -8 V.

msec	Depth (m)*	$40 \log_{10} R + 2\alpha R$ (dB)**	Ross Gain (dB)***
2	1.43	6.22	50.05
5	3.56	22.09	51.79
10	7.13	34.18	53.04
15	10.70	41.27	54.77
20	14.26	46.28	55.05
25	17.82	49.65	56.31
30	21.39	53.39	56.76
35	24.95	56.09	57.41
40	28.52	58.45	58.01
45	32.08	60.52	58.20
50	35.65	62.34	58.39
55	39.21	64.07	58.74

*Sound velocity in fresh water 1426.162 m/sec = 1.426 m/ms at 5^{o}C. Therefore two-way distance = 0.713 m/ms.

**α in fresh water = .00425 dB/m.

***Gain in dB V = $20 \log_{10} \frac{\text{Vrms}}{.0001 \text{ V RMS}}$.

Table 5. Ross System Gain for Surveys Conducted With TVG Ramp Set at -18 V.

Meters	msec	40 Log R + 2 R (dB)	Ross System Gain During Auke Lake August Survey Sensitivity 7.5 Attenuation -12 dB -18 V TVG Ramp (dB)	Ross System Gain During Osprey Lake September Survey Sensitivity 7.0 Attenuation -12 dB -18 V TVG Ramp (dB)
1	1.40	.0085		
2	2.81	12.06	30.1	22.92
3	4.21	19.11	30.63	22.92
4	5.61	24.12	30.88	23.52
5	7.01	28.00	31.82	25.10
6	8.42	31.18	33.06	26.85
7	9.82	33.86	33.25	27.60
8	11.22	36.19	34.48	28.63
9	12.62	38.25	35.27	29.83
10	14.02	40.09	36.65	31.82
11	15.42	41.75	37.78	32.67
12	16.83	43.27	37.73	33.62
13	18.23	44.66	38.89	34.65
14	19.63	45.96	39.55	35.42
14.26	20.00		40.86	35.85
15	21.04	47.17	41.14	36.25
16	22.44	48.30	41.58	37.38
17	23.84	49.36	42.08	37.95
18	25.24	50.36	43.35	38.79
19	26.55	51.31	43.40	39.64
20	28.05	52.21	44.66	40.42
21	29.45	53.07	45.25	41.14

Table 5. (Cont.) Ross System Gain for Surveys Conducted With TVG Ramp Set at -18 V.

Meters	msec	40 Log R + 2 R (dB)	Ross System Gain During Auke Lake August Survey Sensitivity 7.5 Attenuation -12 dB -18 V TVG Ramp (dB)	Ross System Gain During Osprey Lake September Survey Sensitivity 7.0 Attenuation -12 dB -18 V TVG Ramp (dB)
21.4	30.00		45.62	41.51
22	30.85	53.88	45.93	41.65
23	32.26	54.66	46.61	42.67
24	33.66	55.41	47.53	43.11
25	35.06	56.13	48.63	44.03
26	36.47	56.82	49.13	44.61
27	37.87	57.48	49.83	45.15
28	39.27	58.12	50.42	45.80
28.52	40.00		50.58	46.15
29	40.67	58.74	50.78	46.36
30	42.08	59.34	51.39	46.97
31	43.48	59.91	51.73	47.53
32	44.88	60.47	52.30	47.99
33	46.28	61.02	52.73	48.56
34	47.88	61.55	53.31	49.03
35	49.09	62.06	53.70	49.57
35.65	50.00	62.34	53.91	49.71
39.21	55.00	64.07	55.27	51.34
42.78	60.00	65.61	56.41	52.37
46.34	65.00	67.03	57.32	55.31
50	70.00	68.38	58.01	54.02

Table 6. Pulse Volume (m^3) by Depth Interval, Auke Lake Survey, August 2, 1975.

Depth Interval (msec)	Height (m)*	Insonifications/ Fish	Radius (m)	Volume (m^3)
5-15	7.13	110/38 = 2.89	0.377	3.1836
15-25	7.13	667/156 = 4.28	0.558	6.9743
25-35	7.13	191/28 = 6.82	0.8902	17.7526
35-45	7.13	63/7 = 9.0	1.1746	30.9023
45-48	2.14	64/6 = 10.67	1.3921	13.0220

*Sound velocity at 5°C fresh water = .713 m/msec.

A population estimate of fish in Auke Lake was not attempted as several size groups of many fish species were present at the time of the survey. No other population estimates were available for comparison if an estimate had been attempted using hydroacoustic techniques.

Blue Lake, August 27:

An analysis of magnetic tapes from the Blue Lake survey was conducted using the oscilloscope. A total of seven fish targets was detected. This small number of targets did not allow for any meaningful analysis.

Osprey Lake, September 3:

A second survey was conducted on Osprey Lake after the system was recalibrated by Bob Mattie of A.P.L. The system gain (Table 5) and resulting counting threshold (Table 3) were the best during all surveys conducted.

Several problems were encountered during the processes of enumerating fish targets, counting the number of insonifications per target, and determining voltage displacement of targets with the oscilloscope. The fish populations I am working with are sparse. This results in few detections (less than 100 per hour) while sounding. This scarcity of targets makes analysis difficult, as errors in estimation of volume average and target strength are compounded.

The Ross system I am using does not have a 40 $\log_{10}$ R TVG curve, so a wide dynamic range is used by the TVG correction.

The net result of a poor TVG curve allows examination of targets only over a limited depth zone. It may not be possible to look at all targets between 5 and 60 meters, but you could probably look at targets between 20 and 40 meters for example. Basically the TVG error of the Ross is too great. Solution to this problem would be to obtain a receiver with 40 log R curve so the dynamic range of TVG isn't so great. The lack of a wide range of record/playback linearity by the magnetic recorder (Table 1) further complicates this problem.

Other physical problems encountered resulted from having too fast a sounding rate (six times per second) and not having a memory oscilloscope. It is nearly impossible to visually count and measure voltage displacement of images that appear at the rate of six per second.

The above described problems resulted in no population estimate being completed and deteriorated mental health of the analyst.

Orton Lake, September 10:

An analysis of magnetic tapes from the Osprey Lake survey was conducted using the oscilloscope. A total of three fish targets was detected. This small number of targets did not allow for any meaningful analysis.

DISCUSSION

Hydroacoustic System Description and Calibration

A hydroacoustic system was assembled by A.P.L. Calibration procedures were completed in August after field trials on Osprey Lake. The system is mechanically functional but is not adaptable to the application for which it was intended. Modifications or other recommended changes are included in the "Recommendations" section.

Visual Analysis of Acoustic Data

Problems encountered during analysis of acoustic data indicate the system may be of limited value in lakes with scarce fish populations, abundant deadfalls, or shallow shoal areas. Understanding behavior of the fish species being investigated will help in acoustic analysis. Arctic grayling tend to hide in logjam areas where they cannot be detected. Dolly Varden are primarily bottom dwelling, so they are difficult to isolate. Rearing coho salmon in lakes tend to school in shallow shoal areas, so they are easily missed. The easiest fish to enumerate are those which disperse uniformly throughout the midwater column.

No population estimates were completed from any of the acoustic surveys conducted because of problems encountered during analysis. These problems were described in the "Results" section.

An attempt was made to determine if these problems could be alleviated by equipment or procedural modifications. A contractual analysis agreement was arranged with the A.P.L. technical staff. They analyzed the survey tapes and data and recommended required modifications.

Analysis of Hydroacoustic Data by Applied Physics Laboratory

The technicial staff of A.P.L. analyzed the survey tapes and reviewed my analysis procedure. They encountered the same problems I encountered and explained one problem I did not understand. A discussion of their recommendations follows the letter from John Ehrenberg, senior engineer, A.P.L.

TELEPHONE: 543-1300
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APPLIED PHYSICS LABORATORY • UNIVERSITY OF WASHINGTON
1013 NORTHEAST FORTIETH STREET SEATTLE, WASHINGTON 98195

12 May 1976

Mr. A. E. Schmidt
Alaska Department of Fish and Game
P.O. Box 499
Sitka, Alaska 99835

Dear Art:

Dr. Richard Thorne and I have completed our investigation of your acoustic tapes and your analysis procedures. As the first phase of our investigation, Dr. Thorne analyzed the acoustic tapes for Osprey Lake, Blue Lake and Orton Lake. His analysis consisted of using a memory scope to measure the peak amplitude and depth for each individual fish echo above a fixed threshold determined by the noise level. The results of this analysis are attached. There were a number of problems with the recorded data that make it very difficult to obtain abundance estimates from the data. The main problems are discussed below:

1. The acoustic data should have been collected at night. During the day fish are often distributed in schools or near the bottom or shore. This problem was particularly noticeable in Blue Lake and Orton Lake.

2. The pulse repetition rate is much too high. With this pulse repetition rate, false bottom signals appear in the time window being processed. The false bottom signals are due to multiple surface-bottom reflections of the signal. Increasing the time between acoustic pulse will solve this problem.

3. The number of targets is, in many cases, too small for an accurate target strength or sampling volume determination. This problem could have been reduced by using a wider beam width (20° to 30°) transducer.

4. A good 40 log R TVG is required for this type of study. The TVG adjustment made by Bob Mattie prior to the Auke Lake survey significantly improved the TVG characteristic of the sounder. Plots of the amount of TVG correction needed at the output of the sounder before and after the adjustment of the sounder are plotted on an attached figure. The total 30 to 40 dB dynamic range of the tape recorder is required to compensate for the TVG error prior to the adjustment. For this reason, the July Osprey Lake survey tape is of little value.

5. The 100µ volt calibration signal is too low. Ideally, the amplitude of the calibration signal should be similar to that of most of the targets. A better amplitude for the calibration oscillator is 1000µ volts (1 mv).

Dr. Thorne did not further analyze the Auke Lake tape. He felt that your analysis was about the best that could be done considering the problems with the data.

As a second phase of our investigation, I went over your data analysis procedure for Auke Lake and Osprey Lake. The procedure of using the number of insonifications per fish to determine the sampling volume has some inherent problems. At shallow depths the sampling volume is very small and the estimate of average radius, r, will very likely contain a significant random error. If it is assumed that the same fish population is present throughout the total water column, the data from all depth strata can be processed together to improve the estimate for all the depths. The cross-sectional area at any depth, d, is proportional to d^2 or equivalently proportional to t^2 where t is the time from the transmit pulse. Therefore, some of the random error in the data can be removed by doing a least squares linear fit of the measured cross sectional area to t^2. I have done this for the Auke Lake data and the results are shown on an attached figure. A comparison of the sampling volumes calculated using the two techniques is given below.

DEPTH INTERVAL	VOLUME CALCULATED BY SCHMIDT	VOLUME OBTAINED USING REGRESSION FORMULA
5-15 m sec.	3.1836 m^3	1.97 m^3
15-25 m sec.	6.9743 m^3	7.88 m^3
25-35 m sec.	17.7526 m^3	17.73 m^3
35-45 m sec.	30.9023 m^3	31.52 m^3
45-48 m sec.	13.022 m^3	12.78 m^3

It should also be noted that the sampling volume estimation techniques used for the Auke Lake data is only valid if the TVG has been corrected to $40 \log R + 2\alpha R$.

The method of analysis used for Osprey Lake is incorrect. Your expression for the target voltage does not include the effect of the beam pattern. The size of the received echo depends on both the target strength of the fish and its location in the beam (see my letter to you dated September 2, 1975). If you know the target strength distribution of the fish being surveyed, you can calculate the sampling volume for a specific echo level threshold (assuming the TVG has been corrected). Unfortunately, one does not have prior knowledge of the target strength distribution and must measure it in situ (using the dual beam transducer, for example). If you want to discuss this type of analysis further, give me a call.

In conclusion, we are making the following recommendations:

1. Conduct your acoustic surveys at night.
2. Use a lower pulse repetition rate on the sounder.
3. Use a wider beam width transducer.
4. Use a sounder with a good 40 log R TVG.
5. Increase the calibration oscillator voltage to 1 m.v.
6. Process your data with a memory scope.
7. Acquire a dual beam transducer system if you want to acquire good target strength data.

I hope this has answered the questions you had on the use of acoustics for fish population estimation. If you have any further questions, please give me a call.

Sincerely,

John E. Ehrenberg

John E. Ehrenberg,
Senior Engineer

JEE:srm
Attachments
cc: R. Thorne, FRI
R. Mattie, APL
W. Acker, APL

The following comments summarize my interpretation of the recommendations by Drs. Ehrenberg and Thorne:

1. Conducting surveys at night may not alleviate the problems associated with fish distribution. Not all fish distribute themselves evenly throughout the water column. I question whether some species of fish can ever be enumerated accurately via hydroacoustic techniques.

2. Lowering the pulse repetition rate is a necessity. I did not realize that an unidentifiable layer I observed on the oscilloscope was a false bottom echo.

3. Using a wider beam width transducer means obtaining a different transducer.

4. Using a sounder with a good 40 log R TVG means obtaining a different sounder.

5. "Process your data with a memory scope" means purchase a different oscilloscope.

6. "Acquire a dual beam transducer..." is self-explanatory.

In conclusion, the hydroacoustic system I have is not suited to the application intended. Implementation of all recommendations by Drs. Ehrenberg and Thorne may still not result in a system which would satisfy my needs because of fishes' behavioral characteristics.

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OBJECTIVE 2: Determine interspecific relationships for space and food between Dolly Varden and introduced rearing coho salmon in a landlocked lake.

ABSTRACT

Fishery biologists of the National Marine Fisheries Service (NMFS) and Alaska Department of Fish and Game are experimentally utilizing landlocked lakes for coho salmon, Oncorhynchus kisutch (Walbaum), rearing areas. Several of the landlocked lakes contain populations of Dolly Varden, Salvelinus malma (Walbaum). Since physical characteristics of many of these lakes prohibit eradication of the indigenous Dolly Varden, an understanding of interspecific competition for space and food is essential.

A study to determine the interspecific relationships for space and food between indigenous Dolly Varden and introduced coho salmon in Osprey Lake was conducted during summer 1975.

The majority of the Dolly Varden population in Osprey Lake restricts itself to the lake bottom or very near the bottom. A small portion of the population is limnetic. Coho salmon distributed themselves throughout the surface areas of the lake with concentrations near shore. Vertical distribution of coho salmon was limited to near surface. Most remained above the thermocline which occurred at 8 meters.

Food habits of Dolly Varden varied somewhat with habitat occupied and availability of food items at that location. Chironomidae were by far the most important food item. Chironomidae occurred in 80% of all stomachs examined. Other food items, with percentage occurrence of each, included Tricoptera, 30.6; Copepoda, 24.2; Ephemeroptera, 18.5; and Cladocera, 13.4.

Rearing coho fed selectively on the larger copepod, Diaptomus kenai Wilson, during the period when it was available. When D. kenai disappeared from the lake in mid-September, the larger Cladocera became the preferred food item. Chironomidae pupae and adults were of secondary importance.

BACKGROUND

The National Marine Fisheries Service, Auke Bay Fisheries Laboratory, Anadromous Fisheries Investigations Staff, began a cooperative project in 1969 with the Alaska Department of Fish and Game and the U.S. Forest Service. The purpose of the project is to evaluate the biological and economic feasibility of artificially stocking natural lakes with coho salmon, Oncorhynchus kisutch (Walbaum), fry (Anon, 1974). Preliminary studies began in 1969 in the Port Walter area of southern Baranof Island. Experiments with coho salmon rearing in landlocked lakes void of other fish populations were carried out through 1974.

In 1972 an interagency meeting was held at Little Port Walter to review the status of the preliminary lake-stocking program. At that time a decision was made to include additional lakes in the vicinity in the interagency effort. The lakes considered for inclusion were Larry Lake, Osprey Lake, and Borodino Lake.

Preliminary investigations on Osprey and Borodino lakes by NMFS personnel in 1973 resulted in the selection of Osprey Lake as a proposed study site. Alaska Department of Fish and Game stocking records show that Dolly Varden, <u>Salvelinus malma</u> (Walbaum), were introduced to Osprey Lake in 1918. The original proposal was to remove the char prior to planting coho salmon in Osprey Lake, but water volume and cost of treating with rotenone made this prohibitive. A decision was then made to stock advanced coho salmon fry in Osprey Lake. The fry would be reared to about 45 mm and planted in midsummer.

One area which needed to be investigated in order to allow proper evaluation of this stocking was the limnology of the lake. As part of this objective, to determine the relationship of physical, chemical, and biological characteristics of selected lakes to fish production, the Sport Fish Division in cooperation with NMFS conducted comprehensive limnological investigations on Osprey Lake in 1974. Results of this investigation were reported by Schmidt (1975) and Crone (1975). The data provided by this prestocking survey define the limnological characteristics, plankton production, Dolly Varden population, food habits, etc., as a base for future comparisons.

The discussion of the rationale behind stocking coho salmon in a lake populated with char (Anon, 1974) assumed "...that salmon smolt production would be greater without char but holds that a useful level of coho salmon smolt production can occur sympatrically with char."

In 1975 the Sport Fish Division with the cooperation of NMFS conducted a study to determine the interspecific relationships for space and food between Dolly Varden and introduced rearing coho salmon in a landlocked lake (Osprey). The purpose of this report is to present the results of that investigation.

RECOMMENDATIONS

<u>Research</u>

The plankton populations of Osprey Lake should be monitored during the June through September, 1976 period to see if <u>Diaptomus kenai</u> Wilson reestablishes its previous population concentrations.

TECHNIQUES USED

<u>Spacial Distribution and Abundance of Dolly Varden</u>

Spacial distribution and abundance of Dolly Varden was determined by capturing fish in minnow traps and employing mark/recapture ratios.

Fish samples were taken using standard commercial minnow traps and modified minnow traps. Modified minnow traps were 36 inches long and 16 inches diameter with entrance funnels having aperture of 2 inches on either end. Minnow traps were fished systematically throughout the lake so all areas were sampled. Gill nets were fished to determine abundance of pelagial Dolly Varden.

Fish captured in the lake between June 10 and July 15 were marked with an upper lobe caudal clip. This allowed comparison of two population estimates, one made with this year's mark and one made from the recapture of adipose clipped fish which were marked last year. Population size and survival rate were determined from Peterson population estimates based on recapture data from August 1 through September 17. A population estimate of Dolly Varden in the main inlet was conducted between August 8 and September 17. These fish were captured with standard commercial minnow traps. A lower lobe caudal clip was used to distinguish stream residents from lake resident fish.

Spacial Distribution of Coho Salmon

Minnow traps were fished on vertical lines extending from the bottom to the surface to allow comparison of vertical distribution of the coho salmon. The number of fish caught in minnow traps suspended above the lake bottom was compared to the number of fish caught on the bottom.

Determination of Emigration of Dolly Varden Smolt From Lake

NMFS personnel fished a fyke net below the outlet falls in Osprey Creek to determine if and when Dolly Varden emigrated from Osprey Lake.

Food Habits of Fish

Food habits of Dolly Varden and coho salmon were determined by systematic collection of stomach samples throughout the study period. Stomach samples were collected from all representative habitat types throughout the study period. Stomach contents were preserved in 70% ETOH for laboratory identification. Laboratory analysis consisted of identifying and counting organisms.

Zooplankton and Benthos

Zooplankton were collected biweekly by making duplicate vertical tows from 100 m with each of two nets. Nets used were 0.5 m diameter and 3 m long. Straining cloth of the No. 10 Nitex net had aperture of 153 microns and 45% open area, while the No. 20 Nitex net had aperture of 80 microns and 35% open area. Plankton were identified and counted. Dry and ash weight of plankton were determined gravimetrically. Efficiency of nets was not accounted for in calculations. Thermal profiles and Secchi disc readings were taken in conjunction with plankton tows.

Stream drift organisms were collected biweekly by placing two nets in the main inlet. Nets used were 12 inches square, 3 feet long, made of Nitex with pore size of 280 microns, and 45% open area. Benthos were preserved and later identified and enumerated in the laboratory.

FINDINGS

Spacial Distribution and Abundance of Dolly Varden in Osprey Lake

The major portion of the Dolly Varden population in Osprey Lake restricts itself to the bottom or very near the bottom. Minnow traps set on the bottom at any depth throughout the lake captured Dolly Varden. As soon as the minnow traps were suspended above the bottom, the catch was greatly reduced and few, if any, Dolly Varden were captured. Fish were captured down to the 100+ m depth but major concentrations appeared to be above 60 m.

Test netting with vertical gill nets hung in pelagial areas caught no Dolly Varden. No population estimate of gill-net caught fish was possible. The Dolly Varden captured in gill nets were the larger members of the population (mean length 201 mm, range 158-324 mm).

Dolly Varden were captured and marked during the period June 10 to July 15, 1975. These data are presented in Table 1. A Schumacher-Eschmeyer (1943) estimation of the population using these data yields an N of 12,384 fish. The population estimate at the 95% confidence level falls within the range of 8,443 to 23,225 individuals.

Peterson population estimates (Table 2) were conducted on fish recaptured after marking was completed. The population estimate of fish marked in 1974 was 11,479 with range of 10,180 to 13,000 at the 95% confidence level. The population estimate of fish marked in 1975 was 12,327 with range of 10,961 to 13,863 at the 95% confidence level.

The length-age relation of Dolly Varden in Osprey Lake is presented in Figure 1.

Using the above information, a survival rate was calculated for fish which were marked the first year. Ricker (1975) reasons that:

> The number of fish, M_2, marked at the start of the second year, yields R_{22} recaptures that year; thus the rage of exploitation in year 2 is $u_2 = R_{22}/M_1$. Of the M_1 fish marked in year 1, R_{12} are caught in year 2. The number of first-year marked fish still at large at the start of year 2 should be R_{12}/u_2, or $R_{12}M_2/R_22$. The latter number must be compared with the number of marked fish at large at the start of year 1, M_1, to obtain the survival rate over that period:
>
> $$S_1 = \frac{R_{12}M_2}{M_1R_{22}}$$

Applying this formula to the Osprey Lake data estimated a survival rate of 1.07 for summer 1974 to summer 1975.

Table 1. Estimation of Dolly Varden Population by Schnabel Method, Osprey Lake, 1975.

Date	C_t	R_t	M	M_t	R	C_tM_t	$\Sigma(C_tM_t)$	$\hat{N} = \frac{\Sigma(C_tM_t)}{R+1}$
July 10	131	0	131	0	0	0	0	0
14	120	3	117	131	3	15,720	15,720	3,930
18	58	1	56	248	4	14,384	30,104	6,021
23	82	8	74	304	12	24,928	55,032	4,233
25	119	8	105	378	20	44,982	100,014	4,763
26	38	2	36	483	22	18,354	118,368	5,146
27	57	3	30	519	25	29,583	147,951	5,690
30	181	18	163	549	43	99,369	247,320	5,621
July 7	111	8	102	712	51	79,032	326,352	6,276
9	153	22	129	814	73	124,542	450,894	6,091
10	77	6	52	943	79	72,611	523,505	6,541
11	183	20	163	995	99	182,085	705,590	7,052
12	144	16	128	1,158	115	166,752	872,342	7,515
13	211	17	194	1,286	132	271,346	1,143,688	8,593
14	160	11	149	1,480	143	236,800	1,380,488	9,580
15	133	11	122	1,629	154	216,657	1,597,145	10,297
				1,751				

C_t The total sample taken on day t
R_t The number of recaptures in the sample C_t
M The number of fish marked from the sample C_t
M_t The number of marked fish in the lake when the t^{th} sample is drawn
R ΣR_t, the total of recaptures in the experiment
N The population present throughout the experiment

Table 2. Peterson Population Estimates of Osprey Lake Dolly Varden Which Were Marked in 1974 (ad) and 1975 (ulc) and Recaptured, July 16 - September 17, 1975.

Time Period		C	R_{ad}	N_{ad}	R_{ulc}	N_{ulc}	M_{ad}	M_{ulc}
July		388	54	11,317	50	13,356	1,559	1,750
August	1- 7	684	84	12,572	85	13,947		
	8-14	757	94	12,447	101	13,012		
	15-21	890	115	11,982	115	13,449		
	22-30	1,156	168	10,680	158	12,742		
September	1- 7	1,762	239	11,460	245	12,549		
	8-17	1,949	264	11,479	276	12,327		

M Number of fish marked
C Catch or sample taken for census
R Number of recaptures
N Size of population at time of marking

$$N = \frac{(M + 1)(C + 1)}{R + 1}$$

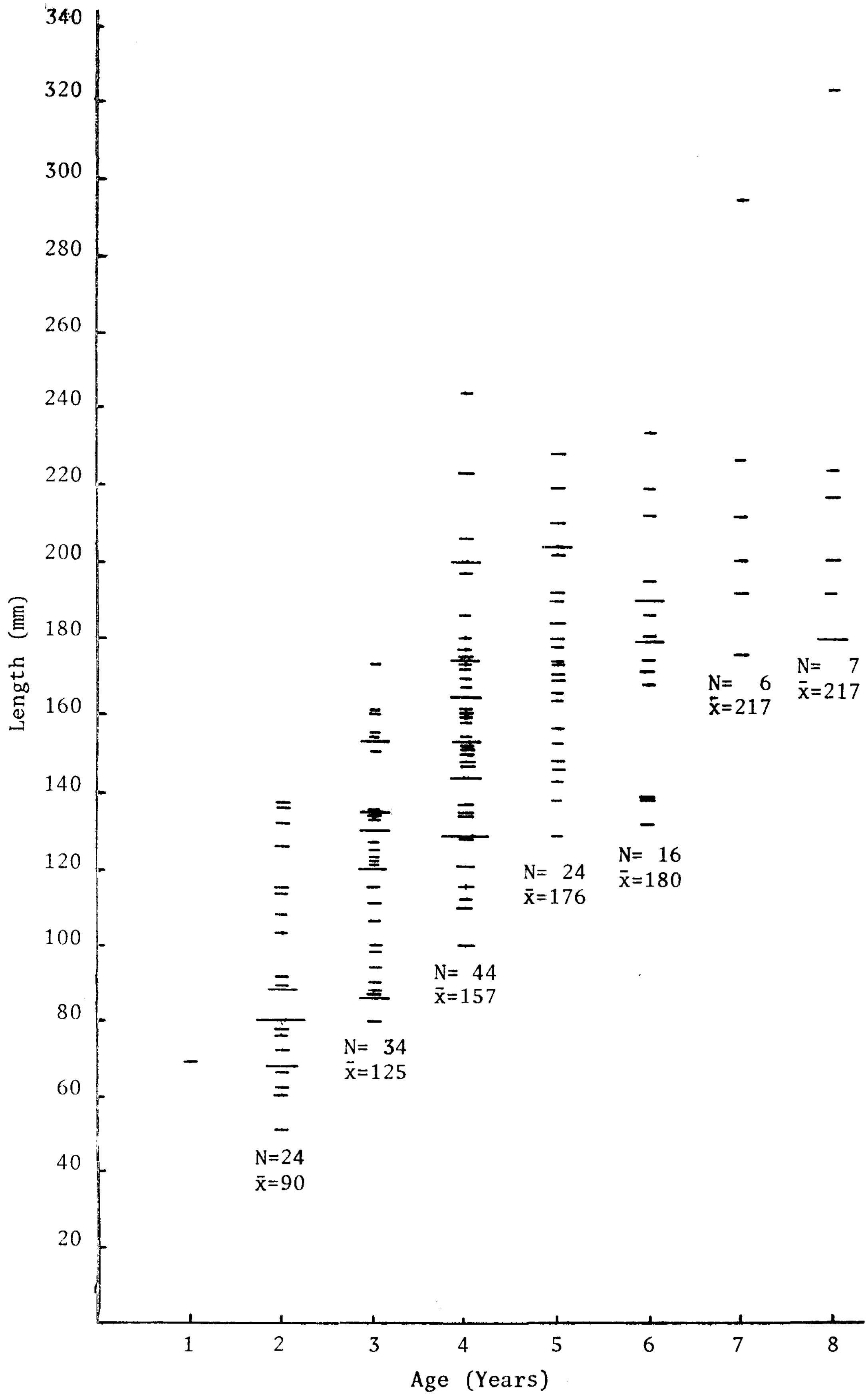

Figure 1. Length-Age of Dolly Varden, Osprey Lake, 1975.

A population estimate of Dolly Varden inhabiting the main rearing stream, Osprey Creek, was conducted during the period June 27 to September 17 (Table 3). The Schnabel estimate is 1,216 fish with range of 900 to 1,398 at the 95% confidence level. Mean length of Dolly Varden in Osprey Creek was 80 mm with a range of 55-160 mm.

Spacial Distribution of Coho Salmon

The west basin of Osprey Lake was planted with approximately 275,000 rearing coho salmon on July 15 by NMFS personnel. This is a planting rate of about 1,000 per acre for the 270 acre lake (Table 4). Osprey Lake has fairly steep sides with limited shoal areas (Figure 2).

Minnow trapping on July 18 showed that no coho salmon were in the limnetic area of the lake; all were inhabiting the shallow littoral areas near shore. Within about a week, July 23, after planting, the coho salmon had spread over about two-thirds of the shoreline, but none were present in the east basin. Within two weeks after planting, the entire shoreline was inhabited. A gradual movement from shore to limnetic areas was then observed, and by mid-August schools of coho salmon could be seen feeding all over the lake surface.

Vertical distribution of coho salmon was limited to near surface of the lake. Baited minnow traps fished on bottom along the shoreline captured coho down to 8 m. Vertical strings of minnow traps fished in limnetic areas caught fish only near the lake surface.

Table 3. Schnabel Population Estimate of Dolly Varden, Osprey Creek, June - September, 1975.

Time Period	C_t	R_t	M	M_t	C_tM_t	$\Sigma(C_tM_t)$	R	$\hat{N} = \frac{\Sigma(C_tM_t)}{R+1}$
June 27	20	0	10	0	0	0	0	0
August 8	92	4	76	10	920	920	4	184
21	57	12	45	86	4,902	5,822	16	342
22	64	1	63	131	8,384	14,206	17	789
September 5	160	19	141	194	31,040	45,246	36	1,223
16	268	69	199	335	89,780	135,026	105	1,274
17	164	77	87	534	87,576	222,602	182	1,216

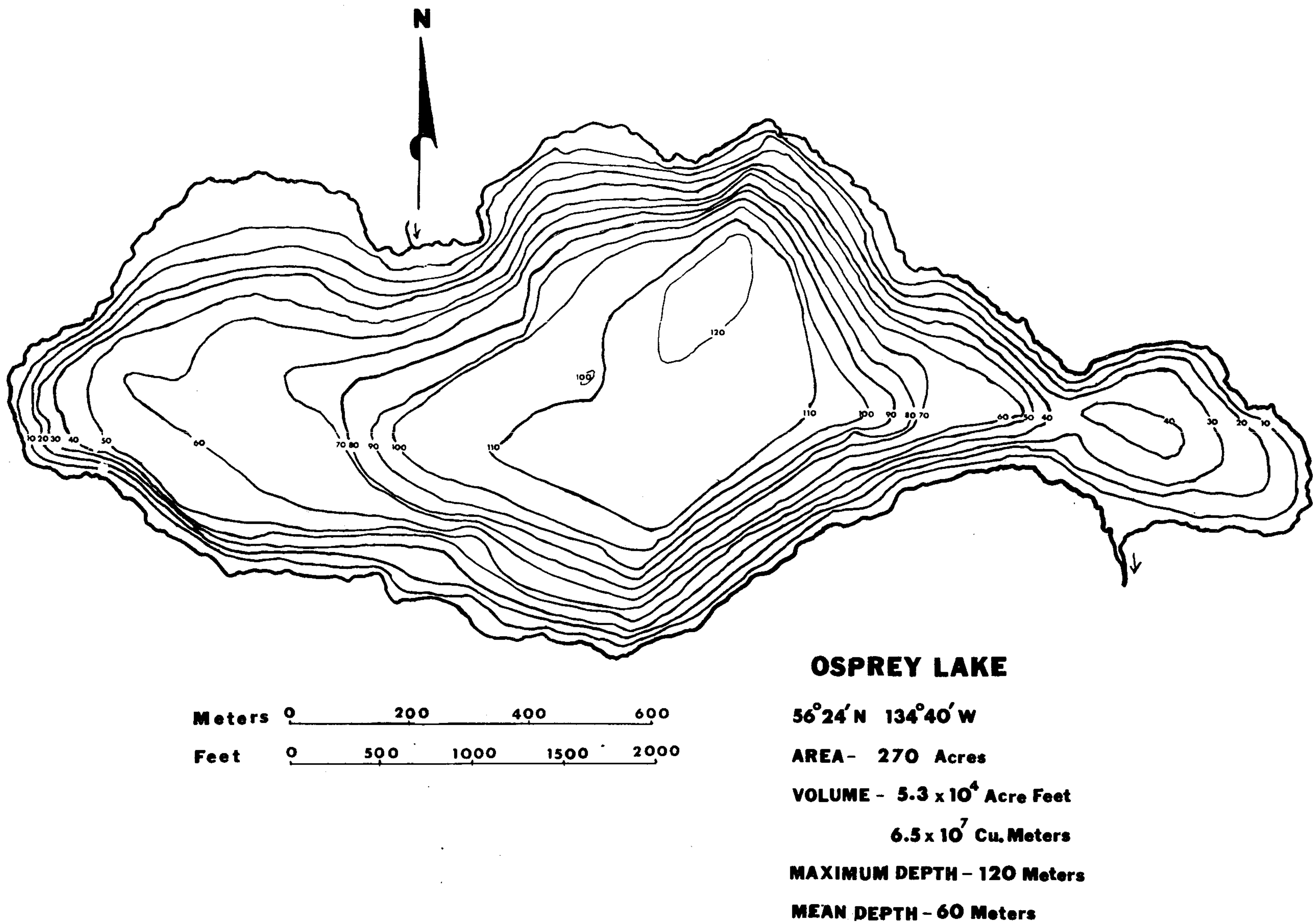

Figure 2. Bathymetric Map of Osprey Lake.

Table 4. Morphometry of Osprey Lake.

<u>Water Area</u>

Hectares	109.3
Acres	270.0

<u>Percent of Depth Zone Areas</u>

0-10 m	10.0	70- 80 m	5.0
10-20 m	8.0	80- 90 m	5.0
20-30 m	8.0	90-100 m	5.0
30-40 m	9.0	100-110 m	7.0
40-50 m	7.0	110-120 m	12.0
50-60 m	10.0	below 120 m	2.0
60-70 m	11.0		

<u>Water Volume</u>

Cubic Meters x 10^7	6.5
Acre Feet x 10^4	5.3

<u>Percent Volume of Depth Strata</u>

0-10 m	16.0	60- 70 m	7.0
10-20 m	14.0	70- 80 m	6.0
20-30 m	13.0	80- 90 m	5.0
30-40 m	12.0	90-100 m	4.0
40-50 m	10.0	100-110 m	3.0
50-60 m	9.0	110-120 m	1.0

<u>Maximum Depth</u> = 120 m   <u>Mean Depth</u> = 60 m

<u>Shoreline Development</u> = 1.57

<u>Development of Volume</u> = 1.5

<u>Shoreline Length</u> = 5,801 m

Minnow trapping for Dolly Varden in the main stream of Osprey Creek produced no coho salmon until mid-September. On September 16, 22 large ($\cong$100 mm) coho salmon were captured in the main stream of Osprey Creek. These lake-rearing coho salmon moved up into the lake the previous week during a high-water flow period.

The west branch of Osprey Creek, a small side branch of the stream delta, was minnow trapped on August 21. Seven coho salmon of size range 55-61 mm were caught. The west branch has slower flow and less water than the main stream. Subsequent minnow trapping of the entire branch estimated the coho salmon population at 50 to 100 fish. These coho salmon entered the stream shortly after planting into the lake and had a much slower growth rate than lake residents. Lake-resident coho salmon at that time averaged over 80 mm in length.

Emigration of Dolly Varden Smolt From Lake

A fyke net fished by NMFS personnel below the outlet fall on Osprey Creek caught nine Dolly Varden smolt. Most were caught during the week of June 15-21. These fish ranged in size from 154 to 212 mm. Average length was 180 mm.

Food Habits of Dolly Varden and Coho Salmon

A summary of stomach content analyses of Dolly Varden by location and method of capture is presented in Table 5. Chironomidae were the food item eaten most often by Dolly Varden. Chironomidae occurred in 79.6% of all stomachs examined. Those fish eating chironomids had an average of 133 organisms per stomach analyzed. The percentage occurrence of other main food items in stomachs examined was: Tricoptera, 30.6; Copepoda, 24.2; Ephemeroptera, 18.5; and Cladocera, 13.4. The number of these organisms per stomach analyzed was: Tricoptera, 3; Copepoda, 336; Ephemeroptera, 5; and Cladocera, 428. Food habits of fish varied somewhat with habitat occupied and food availability at that location, but Chironomidae were by far the most important food item.

Food habits of coho salmon introduced into Osprey Lake are presented in Table 6.

Coho salmon residing in the littoral and shallow limnetic areas of Osprey Lake fed almost exclusively on plankton and Chironomidae. Plankton were the most heavily utilized food source and contributed the majority of production. Chironomidae pupae and adults were eaten as a second choice and as they were available.

Rearing coho salmon fed selectively on the larger copepod, *D. kenai*, during the period when it was available. When *D. kenai* disappeared from the lake in mid-September, the larger Cladocera became the preferred food item.

Growth rate of coho salmon planted in Osprey Lake was monitored by Richard Crone (1975). Data are presented in Figure 3.

Table 5. Stomach Content Analysis of Dolly Varden by Location and Method of Capture, Osprey Lake, 1975.

	Outlet Stream (Below Falls)		Outlet Logjam Minnow Traps		Inlet Stream Minnow Traps		Benthic (75-100 m) Minnow Traps		Littoral (less than 20 m) Minnow Traps		Littoral (less than 20 m) Gill Net		All Locations All Methods	
	Number of Fish = 9		Number of Fish = 22		Number of Fish = 18		Number of Fish = 61		Number of Fish = 21		Number of Fish = 26		Number of Fish = 157	
	Percent Occurrence	Number Organisms	Percent Occurrence	Number Organisms	Percent Occurrence	Number Organisms	Percent Occurrence	Number Organisms	Percent Occurrence	Number Organisms	Percent Occurrence	Number Organisms	Percent Occurrence	Number Organisms
Collembola									4.8	1			0.6	1
Diptera	77.8	123	95.4	1,008	100.0	1,183	86.9	5,448	85.7	165	57.7	7,688	83.9	15,615
Bibionidae			4.5	2									0.6	2
Ceratopogonidae							1.6	1					0.6	1
Chironomidae	44.4	117	95.4	975	100.0	1,157	86.9	6,615	76.2	155	53.8	7,674	79.6	16,693
Adults and Pupae	33.3	66	90.9	796	72.2	84	70.5	4,439	71.4	57	50.5	7,673	68.2	13,015
Larval Forms	33.3	51	68.2	179	100.0	1,073	86.9	2,176	52.4	98	3.8	1	64.3	3,678
Tanypodinae			45.4	41	5.5	1	11.5	10	28.6	8			15.3	60
Diamesinae							3.3	2	4.8	1			1.9	3
Orthocladinae			45.4	79	77.8	486	26.2	56	38.1	43			30.6	664
Chironominae	11.1	22	31.8	46	33.3	20	63.9	2,051	19.0	13			35.7	2,152
Tanytarsini			27.3	18	33.3	20	41.0	801	9.5	3			24.8	842
Chiranomini	11.1	22	13.6	19			31.1	1,247	19.0	10			17.2	1,298
Simulidae	55.5	6			27.8	7			4.8	1	3.8	1	7.6	15
Tipulidae			9.1	4	22.2	14	1.6	1	4.8	1	19.2	12	8.3	32
Empididae			18.2	31	16.7	7			11.3	3	3.8	1	7.0	42
Psychodidae							1.6	1					0.6	1
Ephemeroptera	11.1	1	27.3	26	72.2	112	4.9	3	23.8	13	7.7	2	18.5	157
Baetidae	11.1	1	9.1	3	72.2	89	3.3	2	9.5	8	3.8	1	14.0	104
Leptophlebidae			18.2	15	5.5	2			14.3	3			5.1	20
Ephemerellidae					5.5	1			9.5	2			1.9	3
Heptageniidae					38.9	20							3.8	20
Tricoptera	22.2	2	31.8	25	72.2	64	13.1	17	61.9	55	11.5	3	30.6	166
Limnephilidae	11.1	1	13.6	7	44.4	21	13.1	16	28.6	10	7.7	2	17.8	57
Ryacophilidae	11.1	1	22.7	18	61.1	14							10.8	33
Leptoceridae							1.6	1	38.1	24	3.8	1	6.4	26
Philopotamidae					33.3	23							3.8	23
Psychomyiidae									4.8	21			1.3	21
Plecoptera	22.2	2	4.5	4	38.9	13	1.6	1	4.8	5			8.3	25
Nemouridae	22.2	2	4.5	3	5.5	1							3.2	6
Capniidae					5.5	1							0.6	1
Leuctridae			4.5	1	16.7	5	1.6	1	4.8	5			3.8	12
Perlodidae					11.1	2							1.3	2
Chloperlidae					22.2	4							2.5	4
Neuroptera									4.8	1			0.6	1
Odonata					5.5	1			4.8	1	3.8	1	2.5	3
Coleoptera			18.2	6	16.7	4	6.6	4	9.5	6			8.3	20
Lepidoptera			4.5	1			1.6	1	9.5	3	3.8	1	3.8	6
Hymenoptera			18.2	10							3.8	1	3.2	11
Amphipoda					5.5	1	14.8	16	28.6	8			10.2	25
Gamaridae							13.1	15	23.8	7			8.3	22
Copepoda	11.1	46	4.5	250			27.9	6,307	19.0	3,150	53.8	3,027	24.2	12,780
Cladocera			31.8	4,205			8.2	1,408	33.3	2,775	7.7	620	13.4	9,008
Pelecypoda			13.6	5			6.6	4	4.8	2			5.1	11
Gastropoda			22.7	12			11.4	14	14.3	10			10.2	36
Ostracoda					5.5	70	3.3	3					1.9	73
Oligochaeta							1.6	1					0.6	1
Hirudinea							1.6	1	4.8	1			1.3	2
Hydracarina					5.5	2							1.3	2
Aranea							3.3	2			3.8	1	1.9	3
Salmonidae											26.9	21	4.5	21

Table 6. Stomach Content Analysis of Coho Salmon by Location and Method of Capture, Osprey Lake, 1975.

Fish Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Date	July 24 →																			August 7 →						August 8 →						August 21 →														
Location of Capture	Littoral →																									Outlet Logjam →						Littoral →										Inlet Stream →				
Method of Capture	Baited Minnow Traps (MT) →																															Gill Net (GN) →										Minnow Trap →				
Length (mm)	58	58	59	62	58	54	52	57	55	49	50	54	58	58	58	49	54	54	55	70	70	72	68	67	58	75	67	76	63	68	68	95	91	89	90	95	88	98	87	95	89	59	61	58	59	55
Oligochaeta																																										1				
Cladocera	150	235	100	1	370	12	9	200			10	45			110	50	1	4			3	4		2	100	5	30	170					20	10	60	7	40	20	175	20	160					
Copepoda	285	280	380	240	100	165	5	100		15	5	30	120	25	300	140	340	315	100		100	470	160	600		500	110	530	650	15	450	350	400	450	520	65	950	120	1,200	140	730					
Calanoida	285	280	380	240	100	165	5	100		15	5	30	120	25	300	140	340	315	100		100	470	160	600		500	110	530	650	15	450	350	400	450	520	65	950	120	1,200	140	730					
Cyclopoida																																														
Diptera		1				1		2		1		5		3	1	2				65	5	10		15	94	4	23		4	40	22	2	4	13				2	1		1	62	12	29		76
Chironomidae		1				1		2				5		3	1	2				42	3	9		13	90	4	23		4	40	22	2	4	13				2	1		1	59	12	28		75
Pupae and Adult						1						4		3		2				42	3	9	6	13	87	4	22		4	32	21	2	4	13				2	1		1	55	12	24		68
Larvae		1						2				1			1										3		1			8	1											4		4		7
Empididae																				7	2	1	2	1	3																			1		
Tipulidae																				1					1																					
Muscidae																								1																						
Hymenoptera																								1																						
Homoptera										1										2																									2	
Thysanoptera																				2					16																					
Plecoptera																				3																										
Psocoptera																				8																										2
Coleoptera														1						1																									1	1
Cantharidae																																													1	
Tricoptera																				2	1				4					1													2	1		
Limnephilidae																																											1	1		
Hydroptilidae																				1					4																					
Leptoceridae																				1	1																						1			
Ephemeroptera																									1																			1		1
Baetidae																																												1		
Heptageniidae																									1																					
Collembola																									4																	1	2	1		5
Araneae																				2					1									1												
Hydracarina																																		12								2	2	1	2	2

Table 6. (cont.) Stomach Content Analysis of Coho Salmon by Location and Method of Capture, Osprey Lake, 1975.

Fish Number	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	73	74	75	76	77			
Date	August 22	September 4 →					September 5 →					September 16 →																					
Location of Capture	Littoral →																																
Method of Capture	GN	Minnow Trap →										Gill Net →																			Total Organisms	Percent Occurrence	x̄ Number Organisms
Length (mm)	99	90	86	76	74	71	109	106	99	89	90	107	103	107	102	102	93	105	102	96	92	94	116	95	98	96	97	93	95	96			
Oligochaeta																															1	1.3	1.0
Cladocera	400	50	200	500	400	170	250	40	250	600	500	450	200		450	50	300	400	150	150	450	150	750	80	100	200	400	10	800	450	11,023	77.6	187.0
Copepoda	130	400	350	40	450	600	300	900	200	20	20	1			5								15								14,886	68.2	286.0
Calanoida	130	400			450	600	300	900	200	20	20																				14,475	61.8	308.0
Cyclopoida												1											15								16	2.6	8.0
Diptera		1		8	1				2		2		3		33	13	6	2	19		5	1		2		5	1				604	57.9	13.7
Chironomidae		1		8	1				2		2		3		33	13	6	2	18		5	1		2		5	1				574	56.6	13.3
Pupae and Adult		1		6	1				1		2		3		33	13	6		17		5	1		2		5	1				537	52.6	13.3
Larvae				2					1										1												37	18.4	2.6
Empididae																															17	9.2	2.4
Tipulidae																			1												3	3.9	1.0
Muscidae																															1	1.3	1.0
Hymenoptera										1																					6	5.3	1.5
Homoptera																															18	2.6	9.0
Thysanoptera																															3	1.3	3.0
Plecoptera																															1	1.3	1.0
Psocoptera																															10	2.6	5.0
Coleoptera																															4	5.3	1.0
Cantharidae																															1	1.3	1.0
Tricoptera																								1							12	9.2	1.7
Limnephilidae																															2	2.6	1.0
Hydroptilidae																															5	2.6	2.5
Leptoceridae																															3	3.9	1.0
Ephemeroptera																															3	3.9	1.0
Baetidae																															1	1.3	1.0
Heptageniidae																															1	1.3	1.0
Collembola																															13	6.6	2.6
Aranaea																			1												5	5.3	1.2
Hydracarina																															21	7.9	3.5

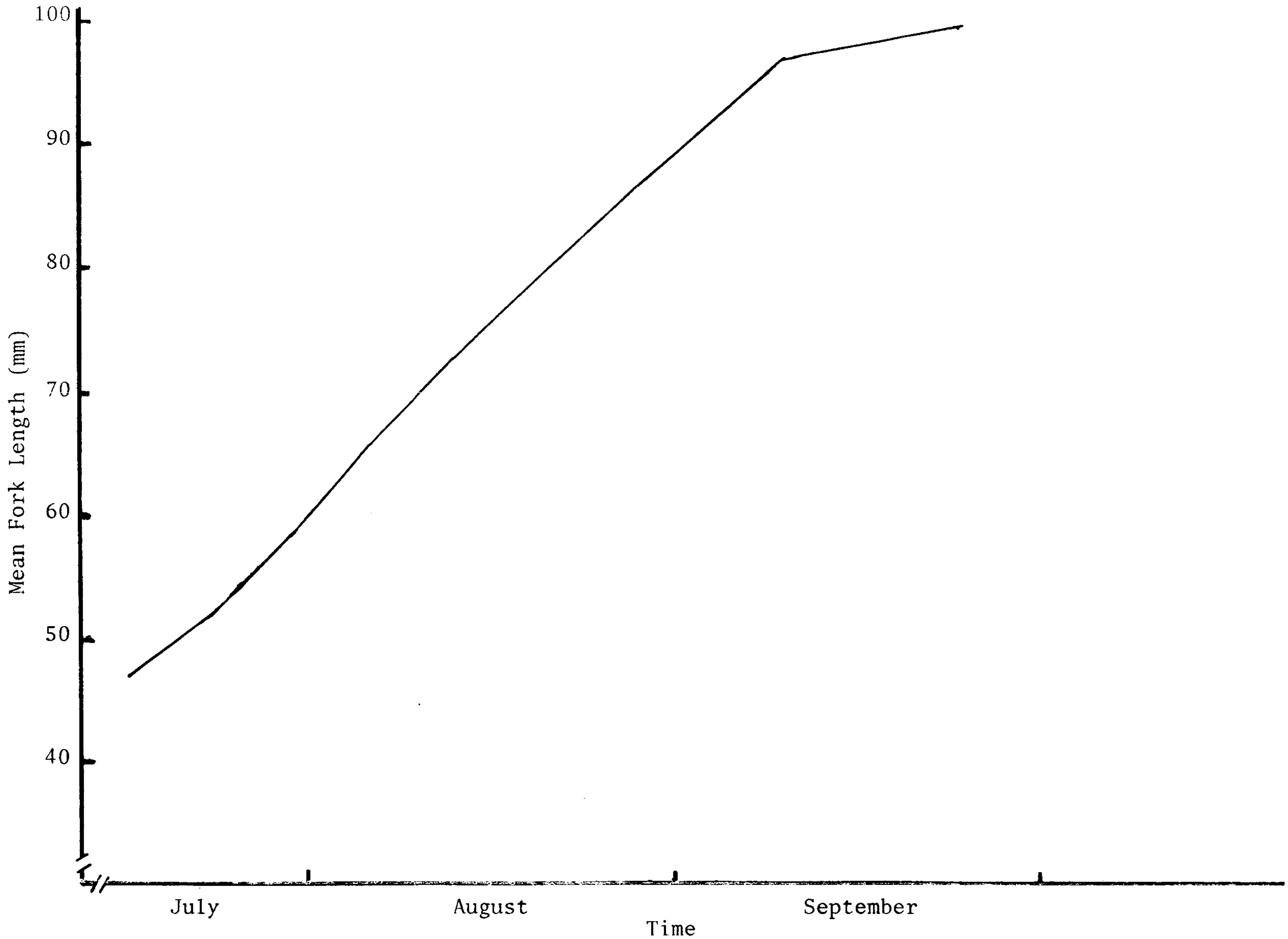

Figure 3. Growth Rate of Coho Salmon Stocked in Osprey Lake, 1975 (Data from Richard Crone, 1975).

Plankton, Benthos, and Physical Consideration

Zooplankton species identified in Osprey Lake are presented in Table 7.

Plankton composition, density, and weight for samples collected from Osprey Lake are presented in Table 8. The most abundant organism throughout most of the study period was the copepod *D. kenai*. This organism reached its maximum abundance in mid-July. The population decreased in late August and disappeared by mid-September.

Identification and enumeration of stream drift organisms from Osprey Creek are presented in Table 9.

Thermal profiles of Osprey Lake show the development of a shallow thermocline in early July (Figure 4). This thermocline moved down to about 8 m and existed throughout the study period.

Secchi disc transparency increased directly with the population increase of *D. kenai* to a maximum of 13.5 m on July 22. When the population of filter feeding *D. kenai* disappeared in mid-September, the Secchi disc visibility decreased to 9.5 m.

Secchi disc transparency by date is as follows: June 6, 11.7 m; June 24, 12.0 m; July 9, 13.0 m; July 22, 13.5 m; August 7, 11.0 m; September 4, 11.0 m; and September 16, 9.5 m.

DISCUSSION

Spacial Distribution of Dolly Varden and Coho Salmon

The majority of the Dolly Varden population in Osprey Lake restricts itself to the bottom or very near the bottom of the lake. Fish were captured down to 100+ m depths, but major concentrations are above 60 m. This segment of the population was estimated at 12,327 (10,951 to 13,863 at the 95% confidence level) using standard marked recapture techniques. The size range of this portion of the population ranged from 68-295 mm. Mean size was 160 mm from a sample of 319 individuals.

A smaller portion of the population is limnetic. Several of these fish were caught in horizontal gill nets. Most were captured near the surface. No fish were caught in the vertical gill nets used. No population estimate of this segment of the population was possible. These fish are the larger members of the population ranging from 158-324 mm. Mean length from a sample of 25 individuals was 201 mm.

Osprey Creek, the main inlet stream to Osprey Lake, is used primarily as a Dolly Varden spawning and rearing area. The population estimate obtained from minnow trapping was about 1,200 fish. The size range of fish caught was 55-160 mm.

Coho salmon situated themselves near the shore in shallow littoral areas immediately after being introduced into the lake on July 15. A gradual

Table 7. Zooplankton Species Identified in Osprey Lake, 1975.

Diaptomus kenai Wilson, 1953.

Specimens from July 22, 1975 No. 80 Nitex sample.

Measured 6 ♀♀ 2.2-2.6 mm (2.4 mm mean)
Measured 11 ♂♂ 1.9-2.2 mm (2.1 mm mean)

Eubosmina longispina (Leydig, 1860).

Specimens from August 20, 1975 No. 80 Nitex sample.

Called Bosmina coregoni Baird, 1857 in Ward and Whipple's "Freshwater Biology"

Daphnia longiremis Sars, 1861.

Specimens from August 20, 1975 No. 80 Nitex sample.

Measured 7 ♀♀ 1.0-1.3 mm (1.1 mm mean)

Daphnia rosea Sars, 1862 emended Richard, 1896.

Specimens from August 20, 1975 No. 80 Nitex sample.

Measured [illegible] ♀♀ 1.5-1.8 mm (1.7 mm mean)

Polyphemus pediculus (Linne, 1761).

Specimens from August 20, 1975 No. 80 Nitex sample.

Holopedium gibberum Zaddach, 1855.

Specimens from August 20, 1975 No. 80 Nitex sample.

Cyclops vernalis Fischer, 1853.

Specimens from July 22, 1975 No. 80 Nitex sample.

Measured 7 ♀♀ 1.1-1.5 mm (1.3 mm mean)
Measured 7 ♂♂ 0.8-1.0 mm (0.9 mm mean)

Kellicottia sp.

Keratella sp.

Table 8. Plankton Composition, Density (organisms per square meter) and Weight (milligrams per square meter) as Collected With No. 10 and No. 20 Nitex Plankton Nets, Osprey Lake, June 25 - September 16, 1975.

Date	June 25		July 9		July 22		August 7		August 20		September 4		September 16	
Depth of Tow	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Mesh Size	No. 10	No. 20	No. 10	No. 20	No. 10	No. 20	No. 10	No. 20	No. 10	No. 20	No. 10	No. 20	No. 10	No. 20
Copepoda														
Calanoida														
Diaptomus kenai	22,750	4,074	26,651	20,713	24,955	28,179	22,750	16,639	15,956	17,657	2,546	1,018	0	
Cyclopoida	8,490	7,807	17,825	12,564	14,601	11,204	18,844	14,601	13,751	10,186	10,018	12,223	12,223	
Nauplii	17,825	25,974	1,528	7,639	17,825	21,900	6,621	21,222	9,167	19,185	10,527	17,148	12,391	
Cladocera														
Daphnia sp.	5,093	1,360	2,378	1,869	11,372	4,416	9,676	6,111	13,410	14,938	13,919	9,844	6,111	
Bosmina coregoni	509		850		1,696	509	4,242	2,037	10,353	12,900	13,919	6,789	5,261	
Polyphemus pediculus			168	341	509	168	168			168				
Holopedium gibberum	168	168		168	341	341	3,565	1,869	6,111	3,906	5,093	1,869	1,528	
Rotatoria														
Kellicottia longispina	341	2,888		1,187		1,187	509	5,602	341	4,571	677	6,453	2,886	
Keratella sp.		509		341		341		1,018		431		341		
Dry Weight	234	137	483	408	726	665	715	623	544	485	245	186	121	180
Organic Weight	208	110	445	377	640	626	677	533	509	446	220	165	106	157
Ash Weight	26	27	39	31	86	38	38	90	35	39	25	21	15	23

Table 9. **Identification and Enumeration of Stream Drift Organisms, Osprey Creek, 1975.**

Date	June 26	June 26	July 9	August 8	August 21	September 5	September 16
Net	I	II	II	I	I	I	I
Ephemeroptera	81	143	95	505	273	30	73
Siphlonuridae	7	6	9	13	2		
Ameletus sp.	7	6	9	13	2		
Baetidae	22	106	58	340	201	25	33
Baetis sp.	22	106	58	340	201	25	33
Heptageniidae	51	29	24	142	62	4	39
Cinygmula sp.	42	14	7	42	33	1	27
Epeorus	9	11	14	100	29	3	12
Rithrogena sp.		4	3				
Leptohlebiidae	1	1	3	9	3		1
Paraleptophlebia sp.	1		3	9	3		1
Ephemerellidae		1	1	1	5	1	
Ephemerella sp.		1	1	1	5	1	
Plecoptera	56	11	29	13	34	18	37
Perlodidae		1			1		
Arcynopteryx sp.		1			1		
Nemouridae	5	2	10	6	16	8	15
Nemoura sp.	5	2	10	6	16	8	15
Leuctridae	19	2	7	4	17	9	19
Leuctra sp.	19	2	7	4	17	9	19
Capnidae	2			1			
Capnia sp.	2			1			
Chloroperlidae	30	6	12	2		1	3
Alloperla sp.	30	6	12	2		1	3
Coleoptera	26	4	12	3	5	3	4
Tricoptera	21	25	14	47	30	1	18
Leptoceridae					1		
Rhyacophilidae	15	21	11	4	2	1	6
Rhyacophila sp.	15	21	11	4	2	1	6
Limnephilidae	3	3		3	1		1
Philopotamidae	3	1	3	40	26		11
Dolophilus sp.		1					
Diptera	134	52	135	221	71	30	39
Psychodidae				1			
Tipulidae	4	6	22	19	20		7
Dicranota sp.	4			19	20		7
Ceratopogonidae			1				
Chironomidae	112	24	101	182	41	30	32
Larvae	98	21	84	75	7	6	2
Pupae	6	1	2	103	18	16	18
Adults	8	2	15	4	16	8	12
Simuliidae	18	22	9	15	9		
Prosimulium sp.	18		9		9		
Rhagionidae			2	1			
Atherix sp.			2				
Empididae				3	1		
Amphipoda					1		3
Gammaridae					1		3
Araneae	2			1			1
Hydracarina	6	2	5	13	17	10	16
Collembola	2		1	4		4	
Hymenoptera			4	2	1		1
Lepidoptera			2				
Hemiptera			2		1	3	
Homoptera						3	
Gastropoda							1
Pelecypoda					3		
Miscellaneous							
Aquatics							
Terrestrials	2		8	4	3 flies		9 flies

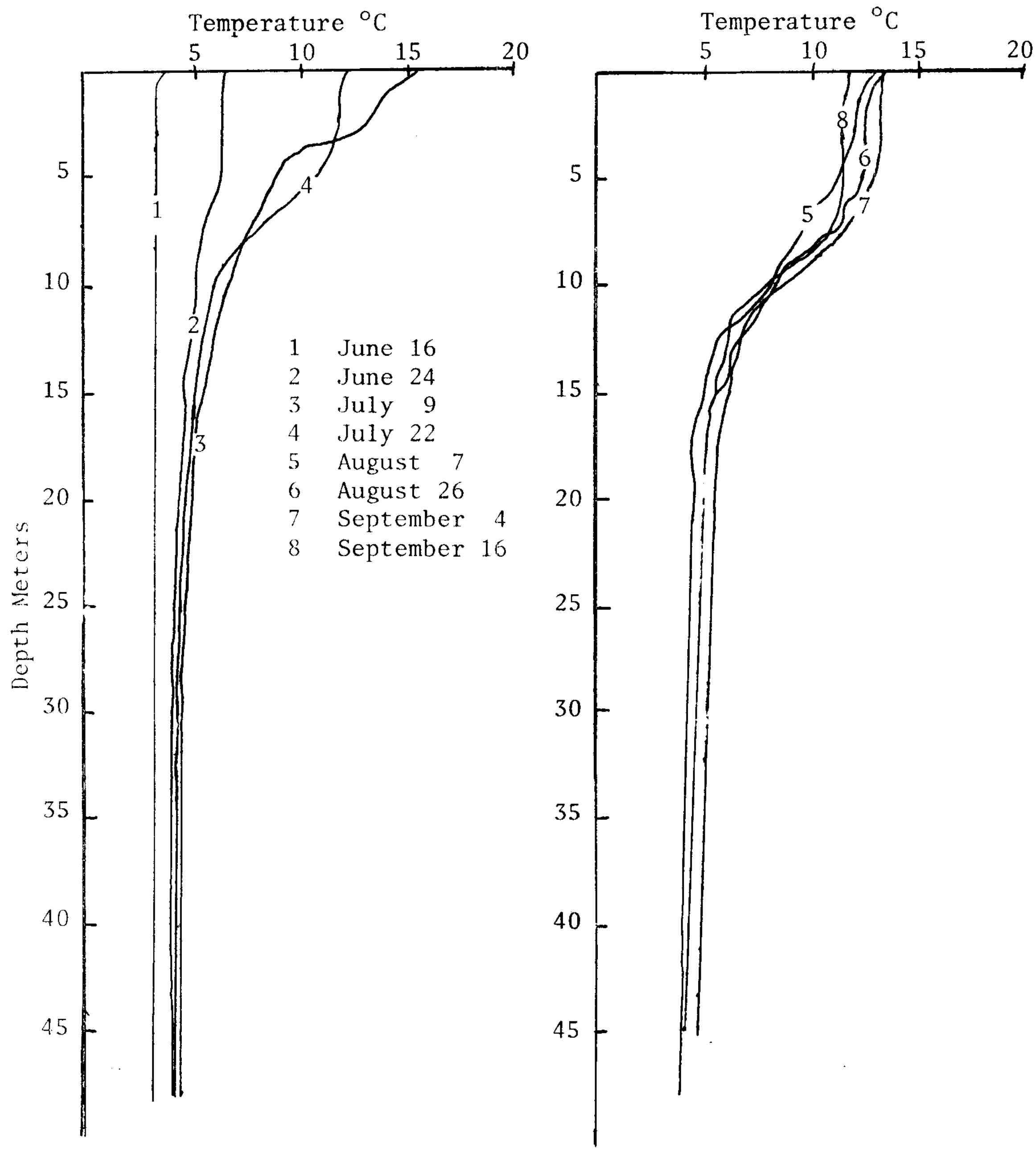

Figure 4. Thermal Profiles of Osprey Lake, June 16 - September 16, 1975.

movement from shore to limnetic areas then occurred by a portion of the population. By mid-August schools of coho salmon could be seen feeding all over the lake surface.

Vertical distribution of coho salmon was limited to near the surface. Most coho salmon remained above the thermocline which occurred at about the 8 m depth.

A small number ($\cong$50-100) of coho salmon inhabited a side branch of Osprey Creek shortly after their introduction into the lake.

The only area where competition for space could occur is in the littoral shoal areas. Both coho salmon and Dolly Varden are present in good numbers and can be caught with baited traps on the bottom. When traps are suspended above the bottom, the Dolly Varden catch is greatly reduced, but coho salmon catch remains unchanged.

Limnetic areas of the lake have few Dolly Varden, but large numbers of coho salmon. Benthic areas are occupied exclusively by Dolly Varden. The inlet stream is occupied primarily by rearing Dolly Varden. Few coho salmon have pioneered into the inlet, probably because of a lack of preferred habitat.

Food Habits of Dolly Varden and Coho Salmon

Food habits of Dolly Varden varied somewhat with habitat occupied and availability of food items at that location. Chironomidae were by far the most important food item and were the only food item of many of the benthic residents. Chironomidae occurred in 80% of all stomachs examined. The next most frequently encountered food items and percent occurrence of each were: Tricoptera, 30.6%; Copepoda, 24.2%; Ephemeroptera, 18.5%; and Cladocera, 13.4%. Mean number of organisms per stomach for fish eating a particular organism are: Chironomidae, 133; Tricoptera, 3; Copepoda, 336; Ephemeroptera, 5; and Cladocera, 428.

The coho salmon introduced into Osprey Lake fed almost exclusively on plankton and chironomids. Plankton were the most heavily utilized food source and contributed the majority of production. Chironomidae pupae and adults were eaten as they were available.

Rearing coho salmon fed selectively on the larger copepod D. kenai during the period when it was available. When D. kenai disappeared from the lake in mid-September, the larger Cladocera became the preferred food item.

A competition for food source exists between Dolly Varden and coho salmon, as both utilize the most available foods. The difference in habitat occupied and preferred food items limits this competition, however. The major area where competition occurs is the shallow littoral area occupied by both species. Undoubtedly the highest area of competition is around the logjam near the lake outlet. Plankton and insect drift here are fed upon by high concentrations of both Dolly Varden and coho salmon. Schools of both species are constantly present.

Utilization of rearing coho salmon as a food source by Dolly Varden occurs but is limited. Of the 156 Dolly Varden stomachs analyzed, 4.5% (7) contained fish remains. All stomachs containing fish remains were from gill-net caught fish over 200 mm in length. Dolly Varden of this size comprise a small part of the population, as discussed earlier.

A more extensive sample of the larger Dolly Varden was collected by Richard Crone during intensive gill netting. Results of this sampling will be reported by him.

Limnological Considerations and Coho Salmon Production

National Marine Fisheries Service personnel planted the rearing coho salmon into Osprey Lake at a very appropriate time. By mid-July the surface water temperature had risen to 12-13°C enabling fish to feed actively. The *D. kenai* population had reached dense proportions, and the fish were large enough to utilize them. The resultant growth rate of rearing coho salmon equaled or exceeded 1 mm/day for a long period. The collapse of the *D. kenai* population resulted in a change of diet and coincided with a subsidence in growth rate.

D. kenai populations were at a maximum during the same time period (late July) this year as last year. The population density reached last year was never observed this year due to cropping by rearing coho salmon. The population on September 4 this year was much lower than last year (2,500 as compared to 21,000 organisms per square meter). If or when *D. kenai* populations disappeared last year is not known, as the last sample taken was September 4. On September 16 this year *D. kenai* populations had completely disappeared.

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OBJECTIVE 3: Determine the impact of any future flow variation from the Blue Lake Dam and Hydroelectric Facility, Federal Power Commission #2230, on the downstream sport fishery of Medvetcha River.

ABSTRACT

The allocation of water stored in Blue Lake Reservoir has become an increasing problem. Increased demand for hydroelectric power by the Sitka area, water requirements of the Alaska Lumber and Pulp Company mill, and streamflow volumes necessary to maintain suitable instream habitat for salmonids have exceeded the storage capacity of the reservoir. A study was conducted to evaluate the impact of future flow variations on the stream's fishery.

Salmonid spawning and rearing areas of Sawmill Creek were identified by observation and minnow trapping. Rearing rainbow trout, Salmo gairdneri Richardson, were located throughout the upstream habitat areas. Pink salmon, Oncorhynchus gorbuscha (Walbaum), were observed in spawning activity and coho salmon, O. kisutch (Walbaum), were located rearing in the downstream habitat. Sawmill Creek was found to receive significant resident and visitor use in angling for rainbow trout.

Available literature was searched and studies discussed to outline the effects of future flow variations upon the downstream habitat and fish behavior. The stream was surveyed, and flow measurements were recorded at selected locations.

It is recommended that the stream's historical base flow pattern be reestablished to support the stream's salmonid population at its previous level. Based upon the daily water discharge records for 1945 through 1957, 22 cubic feet per second (cfs) streamflow discharge should be maintained January through April, 50 cfs during May through November, and 37 cfs during December to provide adequate habitat for salmonids downstream of the controlled diversion valve.

BACKGROUND

Sawmill Creek heads in Blue Lake and flows below a storage dam 1.8 miles southwest to enter the mouth of Sawmill Cove, four miles east of Sitka (Figure 1). It is located geographically at 57°02'50" north latitude by 135°13'35" west longitude (Orth, 1971). It was named in the 1890's by the U.S. Coast and Geodetic Survey for a sawmill reported in 1850 by Captain Tebenkov, IRN, to be located at its mouth. This stream was called "Retu Medvyzhya," meaning "bear river," by the Russians in 1809. It was later known as Medvetcha River before its present name came into popular usage.

Rainbow trout, Salmo gairdneri Richardson, were planted in Blue Lake by the U.S. Forest Service in 1938. The planted rainbow trout were successful in adapting to the lake. Some became stream residents and later developed an anadromous run.

This system supports a recreational fishery during the summer season. The angler effort originates largely from visiting anglers at the Sawmill Creek Campground, which is located along the banks of Sawmill Creek (Figure 1).

The waters of Blue Lake are now controlled by a reservoir storage dam at the head of Sawmill Creek. The dam and hydroelectric generator plant were constructed under the authority of the Federal Power Commission (FPC) in 1960.

The FPC license required in part that reservoir waters be directed into the stream at 50 cfs to maintain downstream fish habitat (see Figure 1).

The natural streamflow pattern of Sawmill Creek reflected considerable fluctuation prior to construction of the hydroelectric project (Figure 2). The streamflow pattern is now affected by the storage capacity of the reservoir and demand for hydroelectric power. The system is subject annually to overflow of lake water over the dam, extreme low flows, and periodic desiccation of some downstream habitat. The annual overflow is due to high rainfall occurring generally in late summer and fall. The low flows are due to the hydroelectric facility's efforts to generate electrical power and maintain a sufficient quantity of lake water in storage for the high power demand period. That period occurs annually during the winter, December through March.

In recent years the water demand for hydroelectric power during the winter was in excess of the facility's ability to produce the desired quantity of hydroelectric power and maintain an adequate volume of reservoir water in storage. In response to this demand, the City and Borough of Sitka requested in January, 1974 that water flow from the controlled diversion valve be stopped down to allow 15 cfs until June, 1974.

Shortly thereafter Sitka requested and received dispensation from the FPC to close the valve until June, 1974. In April, 1974 the FPC directed Sitka to conduct a cooperative study with the responsible State and Federal fishery agencies. The stated objective of this study was to evaluate the effects of flow variations from the diversion valve upon the fishery resources of Sawmill Creek.

RECOMMENDATIONS

Management

To preserve quality instream habitat areas for salmonid production, it is recommended that the controlled diversion valve be opened to allow (1) 22 cfs streamflow discharge during January through April, (2) 50 cfs during May through November, and (3) 37 cfs during December. This streamflow cycle in addition to the runoff received from tributaries approximately duplicates the low runoff for each month during a calendar year. This recommendation is based upon the methodology presented for base flow determination, flow measurements made during this study, and

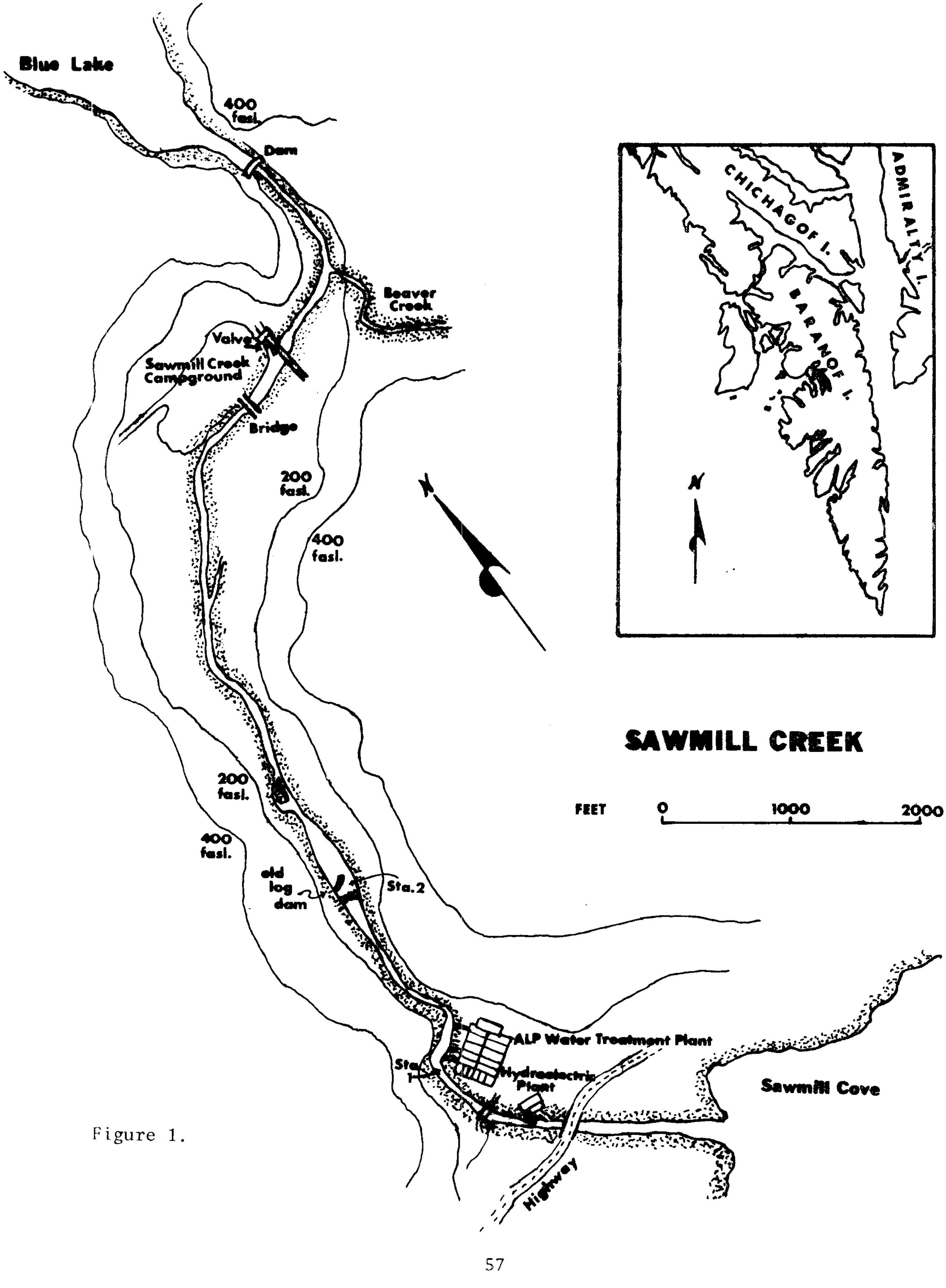
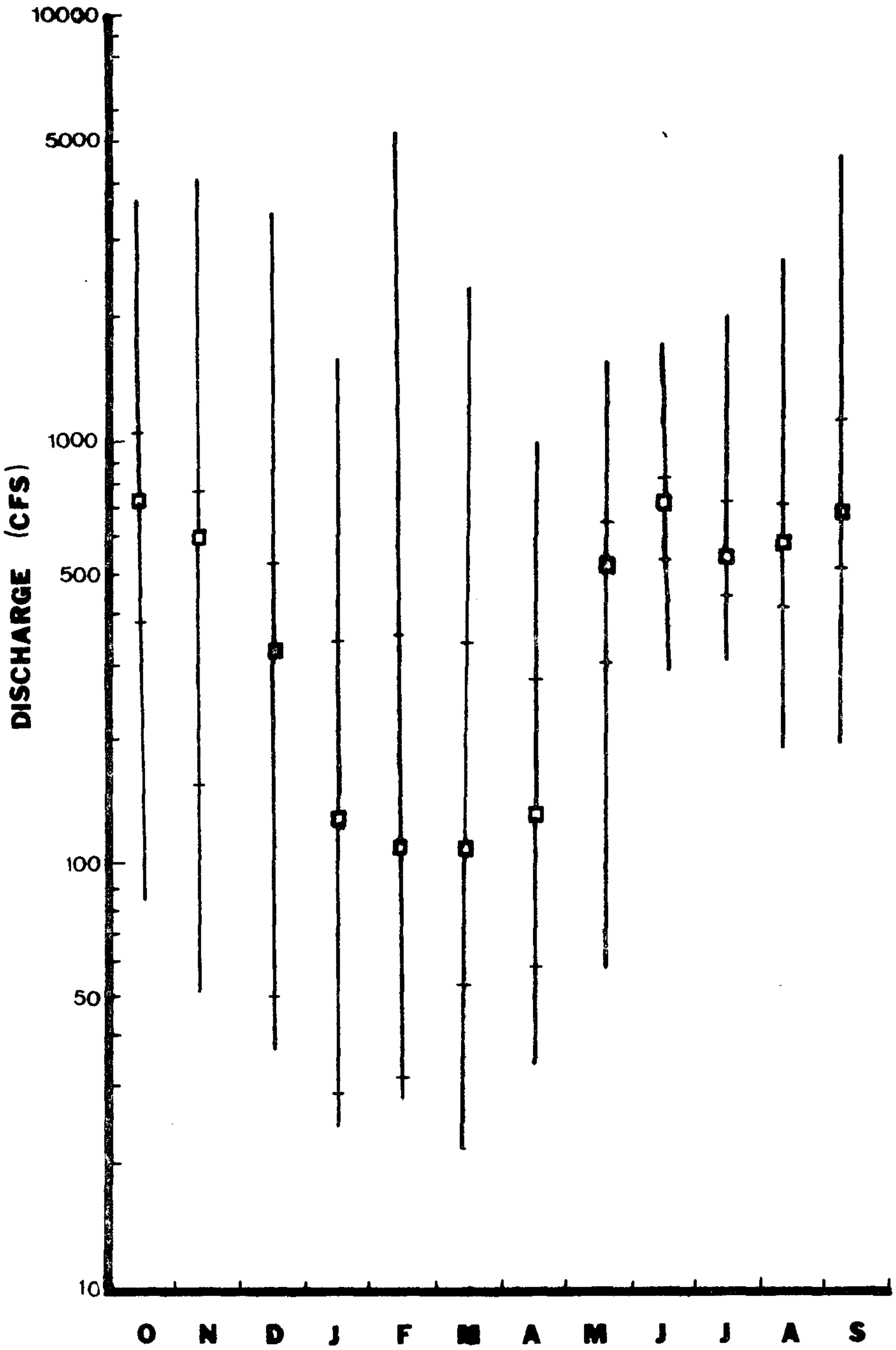

Blue Lake
400 fasl.
Dam
Beaver Creek
Valve
Sawmill Creek Campground
Bridge
200 fasl.
400 fasl.
200 fasl.
400 fasl.
old log dam
Sta. 2
ALP Water Treatment Plant
Sta. 1
Hydroelectric Plant
Highway
Sawmill Cove
SAWMILL CREEK
FEET 0 1000 2000
N
CHICHAGOF I.
BARANOF I.
ADMIRALTY I.

Figure 1.



Mean monthly discharge rate. Range marks indicate the range of monthly means during the 12-year period.

Figure 2. Sawmill Creek Water Discharge Range by Month, Water Years 1945-6 Through 1956-7 (USGS, 1957, 1958a, 1958b, and 1960).

the natural streamflow pattern that occurred prior to the construction of the Blue Lake Dam.

Research

The streamflow requirements for each salmonid species should be studied to determine its critical habitat requirements and those of its food source.

TECHNIQUES USED

Stream Habitat

Salmonid spawning and rearing areas of Sawmill Creek were identified by observation and use of minnow traps. Spawning was not observed, but the stream habitat was surveyed to determine if there was adequate passage upstream and suitable spawning grounds.

Sport Fishery

Anglers who were observed fishing or known to have fished the stream were interviewed to determine the approximate number and size range of fish caught and any changes they had noted in the streamside fishery.

Streamflow Measurements

Streamflow records reported by the U.S. Geological Survey were studied to determine the natural flow patterns that were present before the reservoir dam and hydroelectric facility were constructed. Instream velocities and streamflow volumes were measured by using a Gurley Direct-Reading Flow Meter at selected diversion valve settings.

Literature Search

A review of the literature was made to determine the streamflow requirements and the effects of fluctuations upon resident and anadromous salmonids. Literature on current methodology of determining minimum streamflow levels for the maintenance of fish habitat was searched to find applicable techniques.

FINDINGS

Results

Stream Habitat:

Sawmill Creek contains large areas of suitable spawning grounds. Before construction of the dam, other spawning areas were available in the headwater streams of Blue Lake.

Large volumes of rock were removed from the dam site during construction and deposited as far as the campground area (Figure 1). This area now contains smaller areas of large cobbles and boulders. Suitable spawning gravels of 5-10 cm interspersed with larger boulders in deep riffles characterize the streambed downstream of the campground bridge to the hydroelectric plant (Figure 1). Jones (1975), Bustard and Narver (1975a), and Shepavolov and Taft (1954) indicated these areas to be preferred by steelhead as suitable spawning substrate. During periods of high streamflow, small littoral areas are available to coho salmon, *Oncorhynchus kisutch* (Walbaum), and provide suitable habitat with good overhead cover (Chambers et. al, 1955; Hartman, 1965; and Bustard and Narver, 1975b).

Minnow trapping the stream located rearing rainbow trout in the pool upstream of the valve and through the course of the stream downstream to the pool below the old log dam (Figure 1). Rearing coho salmon were located downstream of the pool and upstream of the estuarine area.

Pink, *O. gorbuscha* (Walbaum), and coho salmon are also known to utilize Sawmill Creek for spawning and rearing. The primary area selected by these two species lies downstream of the old log dam to the confluence of salt water (Figure 1). However, fish passage to this area can be restricted in the stream area just upstream of the water treatment plant due to its narrow width and rocky bottom. Although not determined by live trapping, it is likely that Dolly Varden, *Salvelinus malma* (Walbaum), and cutthroat trout, *Salmo clarki* Richardson, also enter the stream in response to spawning activity of salmon.

Sport Fishing

The instream pools of Sawmill Creek receive significant use by anglers in search of rainbow trout. These fish are reported to range in size from 20 to 26 cm. Larger rainbow trout (50-55 cm) have been caught in Sawmill Creek during the summer in the past few years. Anglers report catching rainbow trout at the base of the dam after overflow periods.

Rainbow trout provide a recreational fishery easily accessible from the Sawmill Creek Campground. This campground is one of two available to summer visitors in the Sitka area and accommodates a large number of visitors.

Streamflow Measurements

Streamflow measurements, compiled by the U.S. Geological Survey, were graphed to illustrate the considerable variation in flow rates during each month for the 12-year monitoring period (Figure 2). These fluctuations are due primarily to periods of high precipitation and extended periods of low precipitation and runoff.

This streamflow pattern was interrupted when the hydroelectric plant came into operation. The water is now taken from the reservoir and is conducted to the hydroelectric plant by a penstock. Water from the plant flows back into the natural stream course. The controlled diversion valve also discharges water from the pipe into the stream course at the campground (Figure 1). The annual precipitation and runoff pattern still varies annually although flow to the stream channel is largely controlled by the storage capacity of the reservoir.

During most "wet" years runoff exceeds the reservoir's storage capacity, and the water flows over the dam. Accurate records are not kept to determine the volume of water overflow during this period of high runoff. This high volume results in a flood stage that flushes and scours much of the residual stream sediment. It also moves numerous stumps and logs from the reservoir over the dam and further downstream. The movement of these debris creates frequent changes in streamflow pattern and digging in the stream substrate. The debris creates temporary habitat for rearing salmonids.

Precipitation diminishes by late fall or early winter, and water ceases to overflow the dam. The reservoir continues to be drawn down and is not refilled until May in an average year (Dwyer, 1975).

During a period that the reservoir waters overflow the dam, the stream habitat receives runoff from the dam, the flow from the diversion valve, and runoff from small tributary streams. During periods of low runoff, the stream receives lake water from the valve and a diminished runoff from the stream's tributaries.

The controlled diversion valve was set at selected apertures, and the resulting streamflow was measured downstream at selected sample stations. The flow estimates are recorded in Table 1.

Station 1 was located upstream of the bridge to the hydroelectric plant, and Station 2 was located at the old log dam (Figure 1). Sample Station 1 was the primary sampling point due to its ease of access and suitable width which permitted wading and measurement of the stream velocity at moderate discharges. Station 2 was selected to determine the discharge rate of water runoff from small tributaries and the water treatment plant to the stream channel upstream of Station 1. The stream in its low runoff period receives an approximate runoff of 10 cfs from small tributary streams. The water treatment plant contributes an additional 10 cfs to the total flow volume at Station 1.

Literature Search

Effects of Streamflow Variations on Salmonids and Stream Habitat

Fisher and LaVoy (1972) found that periodic fluctuations in streamflow create additional habitat during the period that waters overflow a dam and as that "flood stage" subsides that additional habitat would be subject to low water levels and possible desiccation. Water level fluctuations of this magnitude are responsible for the periodic exposure of large areas of the stream's littoral zone and produce a freshwater "intertidal" zone which is somewhat similar to the marine "intertidal." Fisher and LaVoy (1972) observed that the "intertidal" zone of streams differs from its marine counterpart in that (1) the tidal period is

Table 1. Streamflow Measurements of Sawmill Creek.

Sample Station	Sample Date	Controlled Valve Aperature	Wetted Width	Depth Range (Feet)	Mean Depth (Feet)	Stream Velocity Range (Feet/ Second)	Mean Velocity (Feet/ Second)	Stream Discharge (Cubic Feet/ Second)
1	9/16/75	3/4 Open*	68.5	0.8 -3.3	1.1	2.0 -5.0	3.5	165
1	9/18/75	Closed*	62.0	0.2 -2.0	1.0	0.05-3.8	2.0	85
1	9/23/75	2/3 Open*	67.0	0.1 -2.3	1.2	0.05-2.5	1.1	71
1	11/18/75	Closed	35.0	0.4 -1.5	0.9	0.35-1.2	0.8	20
2	11/18/75	Closed	43.0	0.03-1.4	0.6	0 -1.0	0.5	10

*Sampled during period when reservoir waters were flowing over Blue Lake Dam.

irregular, but usually diel; (2) the medium is fresh rather than salt water; (3) the degree of exposure is related to season, being most pronounced during winter; and (4) the zone is of recent origin such that sufficient time has not elapsed to allow the indigenous fauna to adapt. Erman and Leidy (1975) determined that a shift in species composition and abundance could result in available prey by making them unavailable to foraging salmonids or result in low water levels and velocities in which that species cannot survive. Further, this low water period could be significant enough to subject salmonids and their food source to predation, drying, and probable freezing.

Giger (1973), Hooper (1973), Ruggles (1966), and Chapman (1966) found that under low streamflow conditions juvenile salmonids were noted to actively move about the stream looking for prey in the stream's substrate and drift. An initial increase in production and subsequent decline in numbers of stream invertebrates is thought to result from their activity in creating water currents for respiration and displacing themselves in looking for food, making them more noticeable to foraging salmonids. In contrast to high streamflow velocities where greater visual isolation and volume of drift prey organisms are present, greater visibility was present at low flows and permitted more active seeking of prey as well as competing with other salmonids. The competition for territory and food would result in less growth and reduced population size.

Both rainbow trout and coho salmon showed a strong preference for clean gravel substrate. The prolonged presence of silt in the stream's gravels, without frequent flushing, eliminated invertebrate habitat, contributed to the decline in the abundance of invertebrate prey (Giger, 1973; Saunders and Smith, 1965; and Eustic and Hillen, 1954) and inhibited respiration in developing eggs in the stream's gravels. This problem occurred frequently during periods of low streamflow.

Bailey and Evans (1971) evaluated the impact of a proposed hydroelectric installation similar to the facility on Sawmill Creek and determined that the seasonal pattern of stream temperatures would be altered and have an adverse affect upon the natural production of pink salmon. Their analysis of the temperature pattern of the proposed reservoir lake and resulting low flow levels in the stream indicated that the operation of the facility would lower stream temperatures below the normal threshold for embryonic development of pink salmon. Their proposed alternative was to install a tunnel intake to draw water of a desirable temperature from the reservoir that would be required to protect salmon. This "tunnel intake" has a similar function to the controlled diversion valve at Sawmill Creek. The valve would then supply two needed elements: (1) adequate volumes of productive lake water for stream habitat and (2) maintain a desirable stream temperature regime for productive salmonid incubation and development.

Ebel (1971) found another danger in the supersaturation of water with nitrogen gas as large volumes of water run over the spillway of a reservoir dam. This phenomenon has been found to be present even in run-of-the-river dams with small storage reservoirs. The nitrogen supersaturated water causes a gas-bubble disease often fatal to salmonids. The magnitude of this phenomenon upon the rearing salmonids in Sawmill Creek is not known.

Review of Methodology Used to Determine Minimum Streamflow Requirements of Salmonids

Papers by Curtis (1959), Platts (1974), Hooper (1973), Wesche (1973), Tenant et al. (1972), and Milhous (1974) were reviewed to determine the application of their streamflow methodology to prescribing streamflow levels for salmonids inhabiting Sawmill Creek. Milhous (1974) in his discussion concluded that the other present methods were inadequate in prescribing streamflow levels for fish habitat.

Giger (1973), Milhous (1974), Bishop and Scott (1972), and White (1975) point to the lack of knowledge of the effects of fluctuating streamflows upon salmonids and their stream environment. A study is currently being conducted by the Oregon Department of Fish and Wildlife at Elk Creek to develop procedures that can be used in natural streams to estimate the influence of stream discharge on fish production (Keeley and Nickelson, 1974; and Nickelson, 1975).

Milhous (1974) points out the need for a preservation of "base" flow. The base flow must preserve the instream valves. The base flow concept can be defined in one of three ways: (11) base flows are flows that prevent extinction of fish in a stream and allow an allocation of stream waters to be modified with the fish population able to respond to the modification; (2) base flows are flows required to preserve the existing levels of instream use; and (3) base flows are flows below which further reduction in flow will cause a proportionate reduction in the fish population.

Base flows can also be related to the hydrologic base flows. With the application of this definition, the determination of base flow requires a hydrological study. Milhous (1974) points out that the use of hydrologic base flows as preservation flows is based on the assumption that some water must be left in the stream in order to preserve instream valves. The stream ecosystem could be in balance with the pattern of natural streamflow.

The base flow could be determined based upon (1) constant base flow throughout the year based upon a low flow period occurring periodically within a long-term flow cycle that the stream's ecosystem must endure or (2) a variable base flow during the year.

DISCUSSION

Sawmill Creek can provide extensive instream habitat with the potential of supporting a substantial steelhead population in addition to providing spawning and rearing areas for coho and pink salmon. Considering its unique setting and the nearby campground, it provides a unique angling experience that is accessible from the Sitka area road system.

To reestablish and maintain the sport fishery at this level it is imperative that the habitat requirements of the fish population be met. From an examination of the streamflow record summary (Figure 2) it is apparent that the variation of the annual streamflow cycle would be the controlling factor in regulating the productivity of Sawmill Creek. The streamflow measurements made during the period that reservoir waters were overflowing the dam indicate large volumes of water and a suitable velocity rate (See Table 1) to insure flushing of sediment and debris from spawning and rearing areas.

The definitions presented by Milhous (1974) describe the effects that the annual flow cycle has upon the ecosystem. To reestablish previous population levels of steelhead, coho, and pink salmon, the minimum streamflow requirements of these species must be met. The base flows in the annual streamflow cycle must be reestablished by release of productive reservoir waters through the controlled diversion valve. This minimum streamflow or base flow is the level necessary to allow fish production of the stream at its previous level by: (1) enhancing the present production of the invertebrate food source and (2) restoring spawning and rearing areas inaccessible to salmonids at lower flows.

Streamflow volumes and velocity rates in Sawmill Creek are inadequate without the overflowing reservoir waters and if the diversion valve is closed. Small tributaries do provide the mainstream with runoff, as reflected by the flow measurement at Station 2 (see Table 1); however, it is inadequate to maintain a sizable salmonid population without the supplemental flow from the diversion valve.

Using Milhous (1974) method, the base flow can be determined by reading the mean low value of each monthly discharge range (see Figure 2). The release rate for the controlled diversion valve is then derived by subtracting the flow contributed to the stream by tributaries from the base flow for that time period.

To restore quality instream habitat areas for salmonid production based upon the daily water discharge records and the methodology presented for base flow determination, it is recommended that the controlled diversion valve be opened to allow (1) 22 cfs streamflow discharge during January through April, (2) 50 cfs during May through November, and (3) 37 cfs during December. This streamflow cycle in addition to the runoff received from tributaries approximately duplicates the low runoff for each month during a year. This recommendation is based upon the natural streamflow pattern that occurred prior to the construction of the Blue Lake Dam and flow measurements made during this study.

Present methods of measuring streamflow requirements of salmonids are in need of refinement and need to be correlated to feeding and growth rates of fish. At present, streamflow methodologies are correlated to maximizing habitat and not specifically to actual fish requirements. Some studies have determined only the desirable flow rates for adult spawning requirements.

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OBJECTIVE 4: To continue collection, analysis, and organization of all new information on sport fish resources in southeastern Alaska.

ABSTRACT

New and additional information was received and filed in the Inventory and Catalog aquatic systems file. Other researchers were contacted for copies of their recent fieldwork which were put into the file. The collection of reports and other information of interest on aquatic systems in Southeast Alaska is maintained in duplicate in the Juneau and Sitka department offices in order to make information available to resource personnel and the interested public.

BACKGROUND

The Inventory and Catalog File was created to provide a library for the collection of reports of management actions, research data, development plans, and other information of interest in each aquatic system in Southeast Alaska. This file is maintained in duplicate in Juneau and Sitka department offices. It was organized in 1972 (Schmidt and Robards, 1973) to facilitate the dissemination of information to resource agency personnel and the interested public.

RECOMMENDATION

Research

Continue collection, analysis, and organization of available new information on sport fish resources in Southeast Alaska. Further, a summary should be prepared listing the reports on file to advise other researchers of the information available in the Inventory and Catalog Aquatic Systems File.

TECHNIQUES USED

New and additional information was received and filed under the system described by Schmidt and Robards (1973). Other researchers were contacted and copies of their recent fieldwork were requested and received. Other reports are still in preparation so were not received during this reporting period.

FINDINGS

Recent information was received from other biologists on management actions and field surveys of the following systems:

Anderson Creek	Karta Lake	Patching Lake
Auke Creek	Karta River	Sawmill Creek
Blue Lake	Keta River	Starrigavan Bay
Harlequin Lake	Klawak Lake	Swan Lake (Petersburg)
Harriet Hunt Lake	Miller Creek	Swan Lake (Sitka)
Heckman Lake	Naha River	Twelve Mile Creek
Italio River	Nakat Inlet	Wilson River
Kadake Creek	Osprey Lake	

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